Production Research Report No. 135

Factors Affecting

Cottonseed Damage In Harvesting And Handling

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

In Cooperation With the
Agricultural Experiment Stations of
South Carolina, Mississippi, and Texas

Preface

The demand for high-quality cotton planting seed is increasing. Facing rising costs of labor and equipment, cotton producers are becoming more sensitive to the need for getting a good stand of healthy plants at the best planting time. Research has shown the economic value of using seed that will produce vigorous, uniformly growing seedlings. The rising cost of planting seed due to increased costs of seed processing, packaging, storing, handling, and multiple treatments with fungicides and systematic insecticides is also an important consideration.

Coincidently, with the need for higher quality seed, many factors associated with mechanized production have tended to lower the quality of seed. Mechanical harvesters exert forces on the seed cotton that often result in cracked seedcoats. Faster harvesting has created backlogs at gins during peak load periods, resulting in enforced, temporary storage of seed cotton. This storage stimulates adverse biological activity in the seed and lint under certain conditions. To cope with peak demands, ginning has been speeded up, often resulting in physical damage to the seed from gin saws and cleaning and handling equipment.

Changes in production practices associated with mechanization have also intensified the seed-quality problem. Dense canopies of foliage resulting from high levels of fertilizers and moisture encourage boll rot, and long periods of field exposure make the seed more susceptible to biological deterioration and mechanical damage. Mechanical damage in turn makes the seed more susceptible to biological deterioration in storage.

The cotton industry, equipment manufacturers, and research organizations became increasingly aware of the need for research to find the causes of the decreasing quality in seed in the early 1960's. As a result, funds were made available to the Agricultural Research Service in 1965 to research the causes of mechanical damage to seed. Part of these funds were used to finance a 3-year research contract with Clemson University, Mississippi State University, and Texas A&M University to investigate the problems of seed quality associated with mechanical harvesting and handling, with the following general objectives:

1. To determine the effects of static loading, impact forces, and abrasion on cottonseed quality.
2. To determine the relationship of mechanical damage and biological deterioration to methods of delinting, chemical treatment, handling, and storage.
3. To identify sources of mechanical damage in the spindle-type mechanical harvester and relate the influence of seed maturity and weather on mechanical damage.
4. To determine the preharvest environmental factors affecting cottonseed quality.
5. To study the effects of seed cotton storage conditions on seed quality.

Objectives 1 and 2 were undertaken by Mississippi State University, objective 3 by Clemson University, and 4 and 5 by Texas A&M University. Mississippi State University also assumed responsibility for conducting standard germination tests and mechanical damage analyses on seed samples from all three locations.

The highlights of these research results are presented in three parts, corresponding to the three research locations. Semiannual reports are available for loan to anyone wishing to study the research results in more detail.

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Part I. Effects of Mechanical Damage on the Overall Quality and Germination of Cottonseed

Introduction

This phase of the research was conducted by the Agricultural and Biological Engineering Department and the Seed Technology Laboratory of Mississippi State University from 1965 to 1968. Basic studies of forces causing mechanical damage to cottonseed and the relationship of mechanical damage and quality losses in seed treatments, handling, and storage were emphasized. The Seed Technology Laboratory also conducted standard germination tests and analyses of mechanical damage on samples for Clemson University and Texas A&M University under this contract.

Effects of Static Loading, Impact, and Abrasion

Objectives of this phase are summarized as follows:

1. To develop equipment and instruments for applying and measuring static loads, impact forces, and abrasive forces on cottonseed.
2. To determine the effect of static and impact forces on germination and seedcoat crackage of cottonseed.

Static Loading Tests

Equipment and Procedures

A static load-testing device was built to apply a gradual compressive force to an individual seed (fig. 1). This device consisted of a stationary framework, a movable beam, a vertically adjustable loading stop, and a displacement dial indicator. The movable beam was attached to a fulcrum shaft mounted in bearings and balanced so that it could rotate freely. A flat seed platform was welded onto one end of the beam and weights were applied to the other end to provide the desired force on the seed. The weighted end of the beam was supported by a power-driven jack which could be moved up or down at a constant speed.

After the seed and weight were placed in position, the jack was lowered at a constant rate of 0.08 inch per minute until the jack broke supporting contact with the beam. At this instant the maximum force was applied to the seed, signaled by a light bulb. The deformation of the seed was read on the displacement dial.

The cottonseed used in the test was Stoneville 213 variety produced at the Mississippi Agricultural Experiment Station, State College, Miss. The cotton was hand ginned to minimize damage to the seed. Sizes of seed used in the tests ranged from $^{12}/_{64}$ to $^{15}/_{64}$ inch in diameter.

Loading tests were conducted on seeds at 4, 8, and 12 percent (wet basis) moisture content.

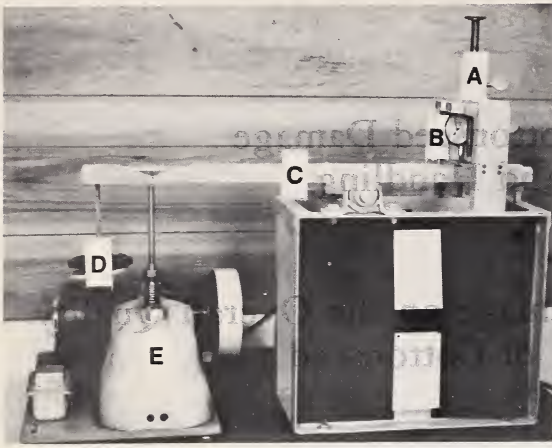

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FIGURE 1.—Static loading testing device: *A*, Adjusable loading stop; *B*, displacement dial indicator; *C*, loading beam; *D*, loading weights; and *E*, power-driven jack.

The seeds were tempered to the desired moisture contents by storing them in controlled humidity and temperature conditions. Loading tests were conducted with the seeds in longitudinal (end) and transverse (side) positions. Ten levels of force, varying from 2 to 25 pounds on each seed, were used. The three levels of moisture content, two orientations, and 10 levels of force gave a 3-by-2-by-10 experimental design that consisted of 60 treatments. Each treatment had four replications with 100 seeds in each replication. After the loading tests were made on each replication, 50 seeds were delinted with acid.

Germination tests were made with both the delinted and undelinted seeds. From the loading tests, the relationship between the force applied to the seed and the deformation of the seed was obtained for each moisture and each orientation. The relationship between the force applied to the seed and the energy absorbed was obtained by integrating the area under the force-deformation curve. From these data a force-energy curve was obtained.

Results

An evaluation of the damage inflicted to the seeds by the applied loads was based on the relationship between the applied force and the percentage of germination. The cottonseeds were more easily damaged when the force was applied to the ends of the seed (fig. 2). Using seeds with an initial germination of 97 percent, the maximum force the cottonseed could withstand without lowering the germination below 80 percent was 26, 25, and 13 pounds for cottonseed at 4, 8, and 12 percent moisture, respectively. For the same percent germination and moisture contents, the maximum force they could withstand with the force applied to the ends was 18, 14, and 10 pounds, respectively.

The mechanical damage was also evaluated by the relationship between the percent germination and the amount of energy absorbed by the seed during the loading tests.

This evaluation showed that the seeds were more easily injured when the force was applied to the cottonseed in longitudinal position. To maintain a germination of 80 percent, the maximum static energy a cottonseed could withstand with force applied to the side was 0.35 inch-pound. For the same germination, the maximum static energy a cottonseed could withstand with the force applied to the ends was 0.20 inch-pound. Therefore, cottonseed handled in bulk should not be allowed to absorb more than 0.20 inch-pound.

Dynamic Impact Tests

Equipment and Procedures

The impact testing device consisted of a balanced arm with a rotational velocity necessary to give the desired impact (fig. 3). The arm had a cantilever beam attached to one end. When impact was desired, the seed, which was suspended on the end of a vacuum tube, was lowered into the path of the beam. After the seed was struck by the beam, it was caught in a padded box. These tests were conducted to determine the effect of different velocities of impact on the germination and the amount of seedcoat crackage.

Tests were run on four varieties of cottonseeds, at four or five different moisture contents, and three seed orientations. The four varieties used were Dixie King, Coker 100, Stoneville 213, and Deltapine Smooth Leaf.

The moisture content ranged from 6 to 15 percent in approximately 2 percent intervals. Impacts were made on the side, radicle end,

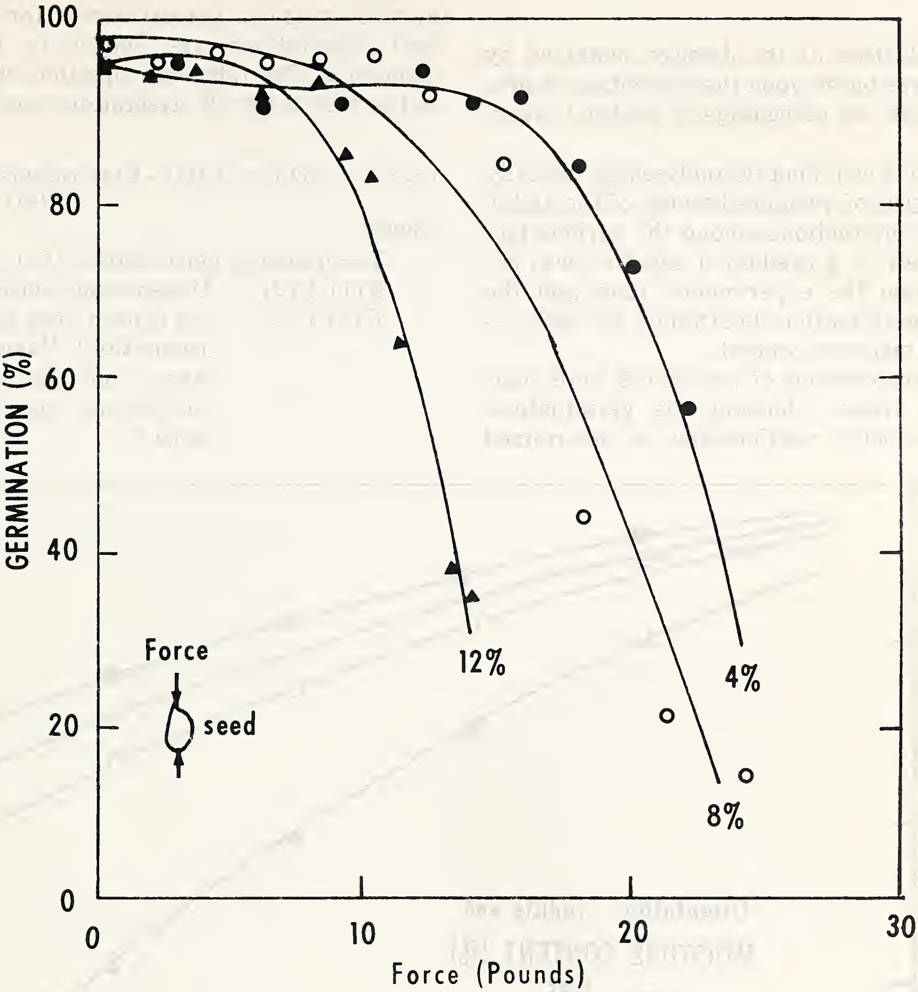

FIGURE 2.—Germination versus force for delinted seed in longitudinal position at 4, 8, 12 percent moisture content.

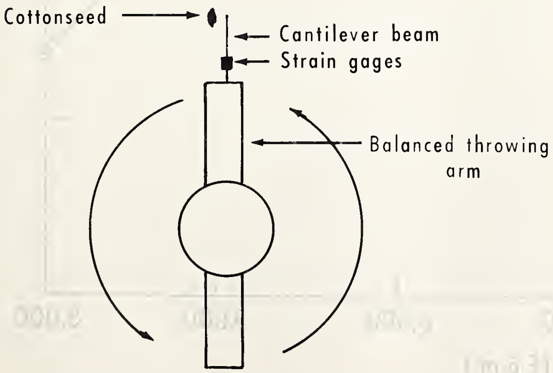

FIGURE 3.—Schematic of impact device.

and chalazal end of the seed. Each seed received only one impact. The velocity of impact ranged from 3,000 to 8,000 feet per minute (f.p.m.) in 1,000-foot intervals.

The six levels of velocity, five levels of moisture content, and three orientations gave a 6-by-5-by-3 experimental design that consisted of 90 treatments. Each treatment had four replications with 100 seeds in each replication.

After the impact tests were performed, 50 seeds from each replication were acid delinted to study damage by acid and to ascertain damage to seedcoat. Germination tests were made with both the delinted and undelinted seeds.

Results

The evaluation of the damage sustained by the seeds was based upon the percentage of germination and the percentage of seedcoat crackage.

The results could not be analyzed statistically by an analysis of variance because of the highly significant interactions among the various factors. Therefore, a prediction equation was developed from the experimental data and the predicted germination determined for each velocity and moisture content.

The interpretations of the results were made from the graphs showing the germination-moisture-velocity relationships as determined by this equation. Typical curves for the three seed orientations are shown in figures 4 through 6. The following equation was chosen as the best fit for all orientations and varieties.

$$Y = B(1) + (\text{velocity})^2[B(2) + B(3)\ \text{moisture} + B(4)\ (\text{moisture})^2] \quad (1)$$

where:

Y=predicted germination (%)

$B(1), B(2), B(3), B(4)$ = Dimensional constants (values depend upon variety and orientation). Values for constants and the correlation coefficients are given in table 1.

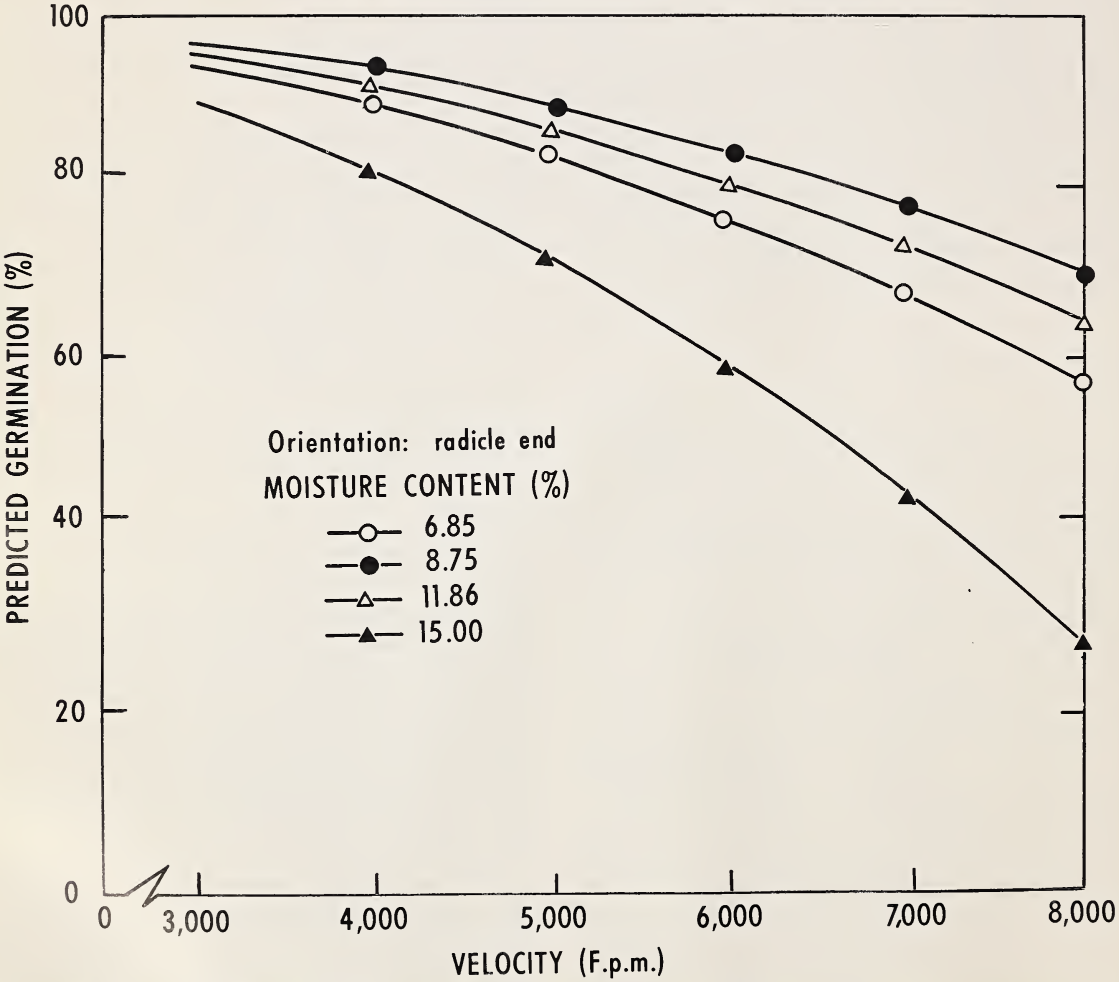

FIGURE 4.—Predicted germination versus velocity of impact, Stoneville 213 variety, radicle-end orientation.

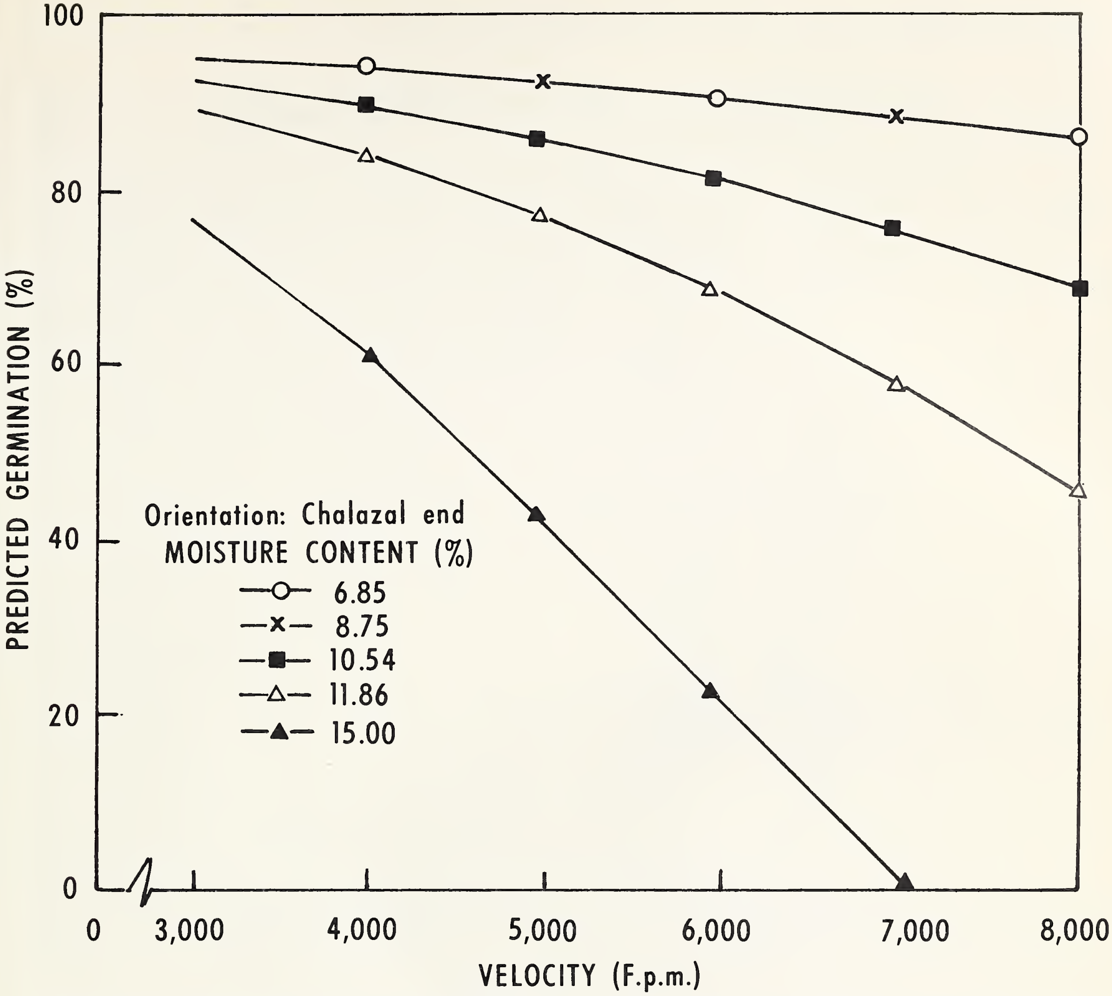

FIGURE 5.—Predicted germination versus velocity of impact, Stoneville 213 variety, chalazal-end orientation.

The moisture content is expressed as a whole number in the equation. This equation is applicable only within the limits of this particular experiment.

The varietal differences had little or no influence upon the amount of damage sustained by the seeds. Less damage to germination occurred in all orientations when the seed moisture content was between 9 and 12 percent (wet basis).

In all varieties, the seeds impacted on the radicle end sustained greater damage to germination than those impacted on the side or chalazal end.

Therefore, the radicle-end orientation would limit the velocity at which seeds could be impacted without causing excessive damage to germination. The relationship of germination and velocities for seeds in the radicle-end orientation indicates that 6,500 f.p.m. would be the approximate maximum velocity at which seeds could be impacted without lowering the germination below the certification standard of 80 percent, assuming that the initial germination was above 90 percent.

A greater percentage of seedcoats were broken when the seeds were impacted on the side or chalazal end. At a velocity of 4,000 f.p.m., the maximum crackage of seedcoats was only 15 percent that occurred in the Coker 100 variety in the side orientation (fig. 7). At the

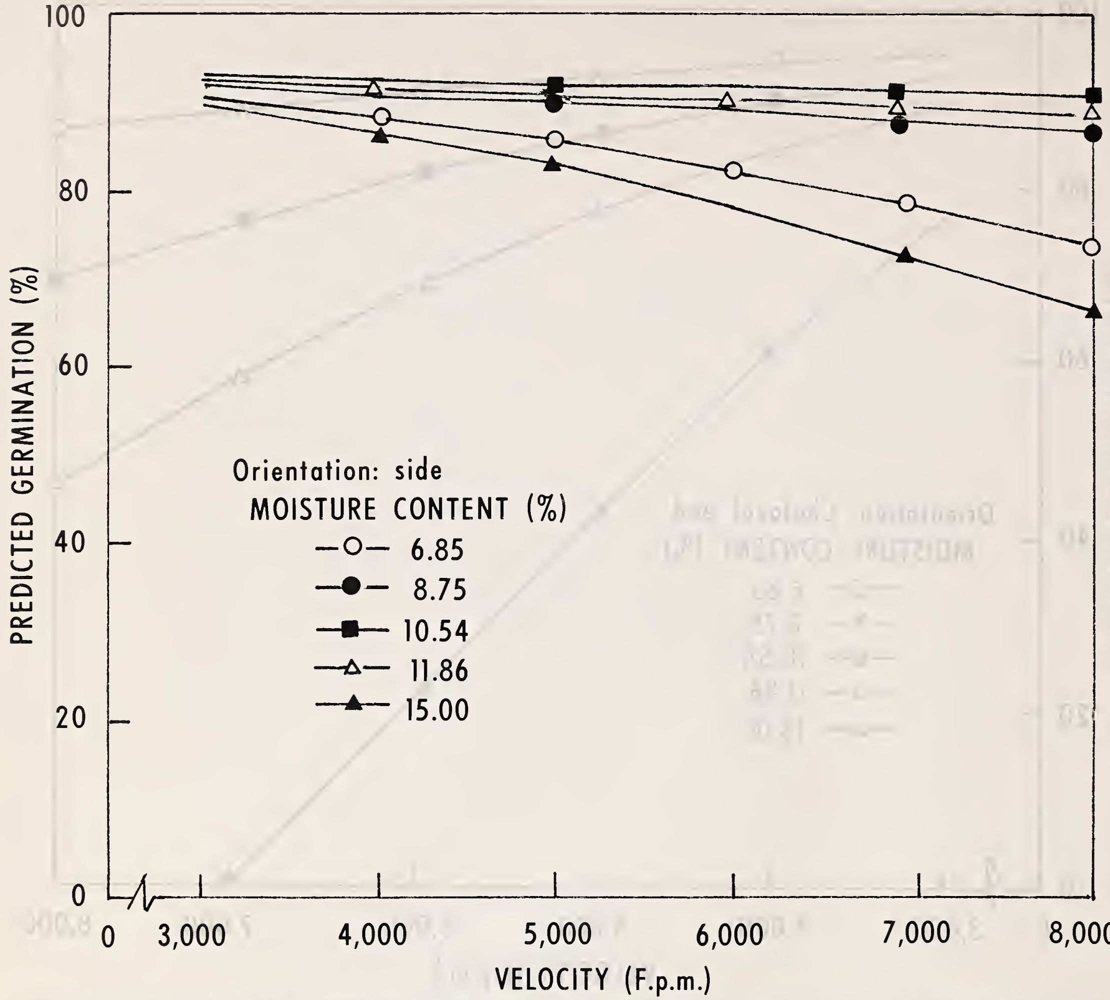

FIGURE 6.—Predicted germination versus velocity of impact, Stoneville 213 variety, side orientation.

5,000 f.p.m. velocity, the percent crackage was 40 percent in the Dixie King variety in the side orientation. The percent crackage for velocities above 5,000 f.p.m. increased rapidly in all varieties of seeds in the side- and chalazal-end orientations.

The seeds impacted on the radicle end had the lowest percentage of seedcoat crackage (fig. 7). While the seeds impacted on the side and chalazal end had the highest percentage, they also had the highest percentage of germination. However, all the cottonseeds were germinated soon after being damaged. If the seeds had been stored for several months after being damaged, the decrease in percent germination would have probably been greater. The limiting velocity here would be determined by the percentage of seedcoat crackage.

One test was conducted to determine the effect of more than one impact. With a 3,000 f.p.m. impact velocity, seedcoat crackage did not increase up to three impacts. However, with a 6,000 f.p.m. velocity the percent crackage increased in practically a linear fashion from 7 percent for one impact up to 37.5 percent for three (fig. 8). This finding indicates that the repeated impacts have a cumulative effect, and illustrates the importance of using the min-

TABLE 1.—*Constants used in prediction equation and correlation coefficients* (*R*)

Variety and constants	Orientation		
	Radicle end	Side	Chalazal end
Stoneville 213			
B (1)	99.80	93.58	96.64
B (2)	-2.83×10^{-6}	-2.16×10^{-6}	-2.47×10^{-6}
B (3)	$.489\times10^{-6}$	$.402\times10^{-6}$	$.605\times10^{-6}$
B (4)	$-.025\times10^{-6}$	$-.019\times10^{-6}$	$.039\times10^{-6}$
R	.794	.623	.880
Coker 100			
B (1)	100.00	96.9	94.49
B (2)	-4.59×10^{-6}	-2.86×10^{-6}	$-.699\times10$
B (3)	$.766\times10^{-6}$	$.441\times10^{-6}$	$.134\times10$
B (4)	$-.034\times10^{-6}$	$-.019\times10^{-6}$	$-.007\times10$
R	.889	.868	.440
Dixie King			
B (1)	97.04	90.33	----------
B (2)	-3.64×10^{-6}	-3.14×10^{-6}	----------
B (3)	$.63\times10^{-6}$	$.480\times10^{-6}$	----------
B (4)	$-.029\times10^{-6}$	$-.018\times10^{-6}$	----------
R	.887	.908	----------
Deltapine Smooth Leaf			
B (1)	100.81	96.102	----------
B (2)	-1.77×10^{-6}	-3.72×10^{-6}	----------
B (3)	$.284\times10^{-6}$	$.626\times10^{-6}$	----------
B (4)	$-.015\times10^{-6}$	$-.027\times10^{-6}$	----------
R	.697	.868	----------

imum permissible velocities where seeds are subjected to impacts.

In a further analysis, instruments were attached to the impact apparatus to determine the quantity of energy absorbed by the seed during impact. The major purpose in determining the quantity of energy absorbed by the seeds upon impact was to compare the effect of a slowly applied load versus an impact. The effects of slowly applied loads and impacts are compared in figure 9. At energy absorption levels above 3 inch-ounces, the slowly applied loads are more detrimental to seed germination than dynamic loads.

Abrasion Tests

Equipment and Procedures

The apparatus for determining the kinetic frictional resistance of cottonseed is shown in figure 10. The cottonseeds were stuck to the belt and then pulled along the bottom side of the friction plate attached to the piston in the loading unit.

The belt was mounted on a conventional 6-inch belt sander. The top section of the belt was supported by a steel table to hold the seed firmly against the friction plate. The belt was driven by a motor of variable speeds so that the belt speed could be changed easily.

The loading unit consisted of an automotive piston and a sleeve closely fitted to each other. The piston was free to move vertically with very little friction as the seed was pulled under the friction plate. The horizontal friction force was transmitted to the load cell attached to the side of the ring supporting the sleeve. The desired normal force on the seed was obtained by placing weights on top the piston. The normal force on the seed was the total weight of the piston, friction plate, and weights. Stoneville 213 variety was used in the tests. The seeds were ginned on a laboratory roller gin, and then conditioned to the desired moisture con-

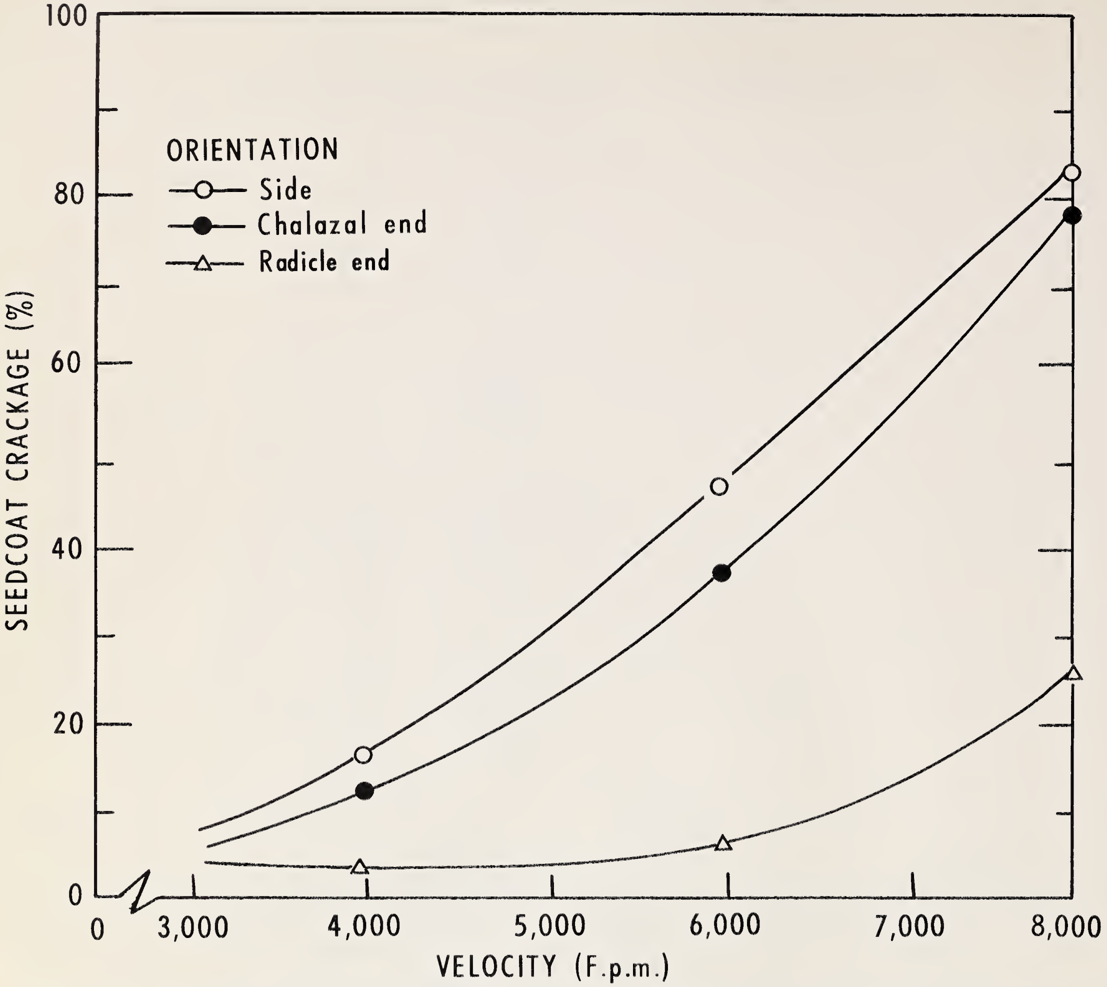

FIGURE 7.—Effect of velocity and orientation on seedcoat crackage for all moisture contents, Coker 100 variety.

tent by placing them over various salt solutions inside closed containers.

Gin-run and delinted cottonseed were used in the test. Seeds were delinted by scraping with a razor blade. Subjecting the seeds to strenuous delinting processes, such as acid delinting, was undesirable. Kinetic friction coefficients of cottonseed against galvanized metal, teflon, and plywood were determined for two types of cottonseed, three moisture contents, three velocities, and three normal forces. The three velocities were 5, 10, and 15 inches per second. Preliminary tests had shown that 15 inches per second was the fastest speed at which the apparatus could be operated because of the time required to get the seed up to that velocity.

The three normal forces were 2, 4, and 6 pounds per seed because static load tests had shown that forces ranging from 8 to 16 pounds would crack the seedcoat. The three moisture contents were 6, 10, and 14 percent (wet basis). These values are representative of the range of normal moisture content in which cottonseed is handled.

The tests were conducted in an environment chamber in which the temperature and the relative humidity (R.H.) were controlled. The temperature was maintained at 23° to 24° C. The

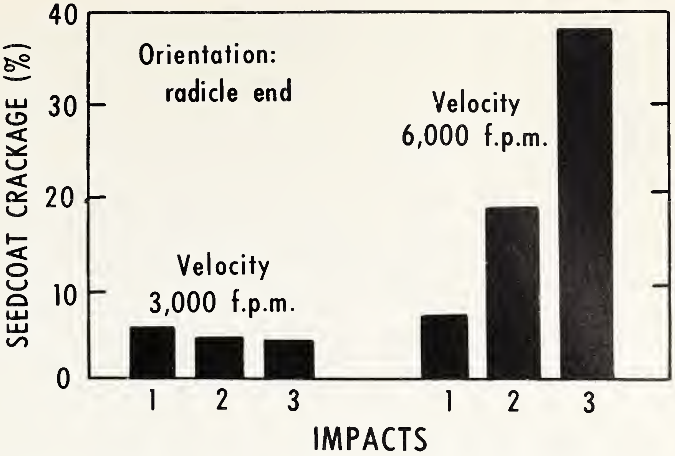

FIGURE 8.—Effect of number of impacts (1,2,3) on cottonseed damage at two impact velocities, Stoneville 213 variety, with 9.97 percent moisture content.

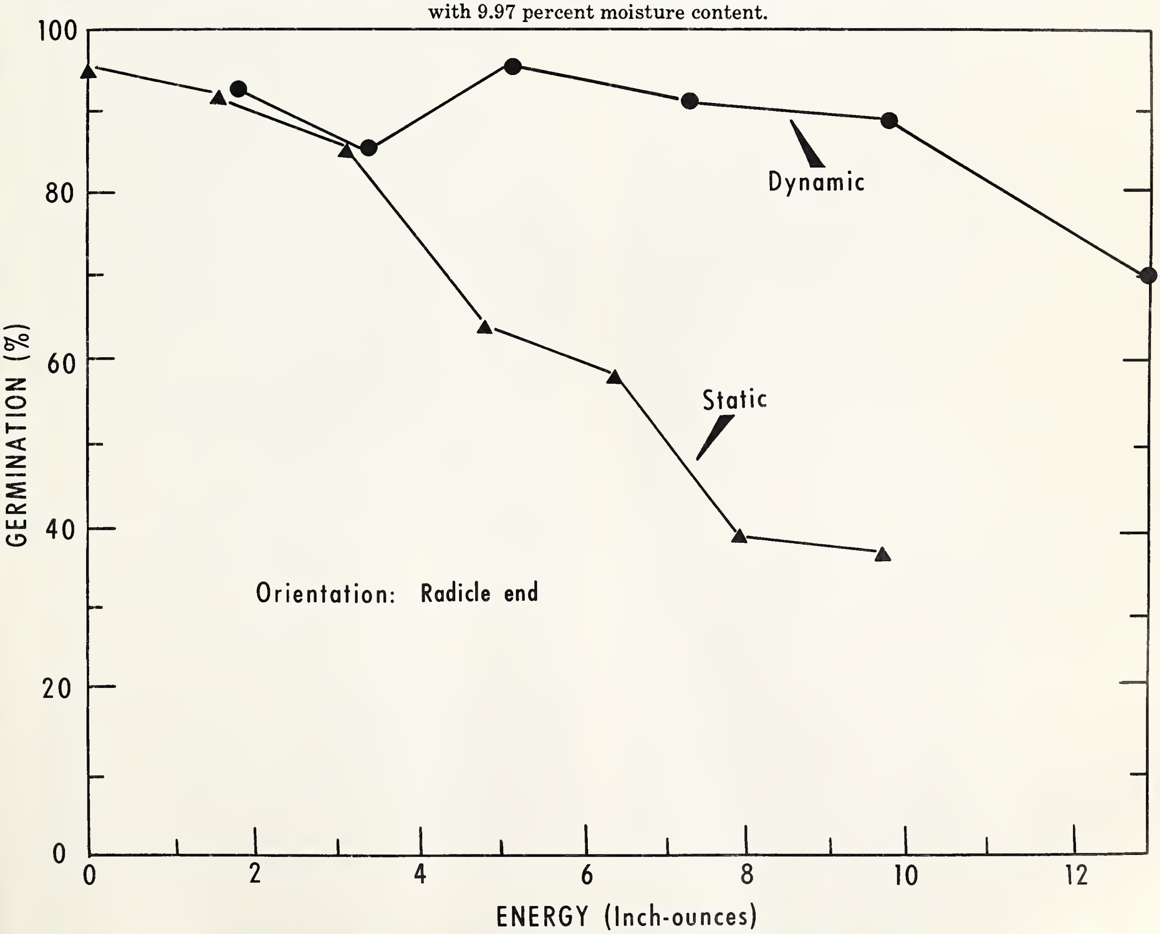

FIGURE 9.—Effect of static and dynamic energy absorption on cottonseed germination, Stoneville 213 variety, with 12 percent moisture content.

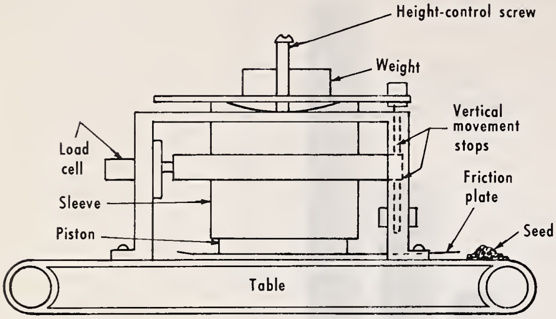

FIGURE 10.—Kinetic friction apparatus.

relative humidity was adjusted to be in equilibrium with the moisture content of the particular seeds being tested.

Findings from other research[1] have shown that the relative humidity of the air in contact with the friction surface will affect the coefficient of friction. The seed moisture content-relative humidity relationships were as follows (1) 6 percent moisture – 31 percent R.H.; (2) 10 percent moisture – 71 percent R.H.; and (3) 14 percent moisture – 80 percent R.H.

The metal and teflon surfaces were conditioned before each series of tests for a particular seed moisture content. First, the surface was cleaned with denatured alcohol, and then 100 seeds were run past the surface before measuring force. By first conditioning the friction surfaces, the friction force was almost constant for all the tests. The plywood surface was not cleaned because a solvent would remove the natural wood oils.

One seed was tested at a time. Each seed was attached to the belt with clay. The seeds were positioned so that the side of each would be against the friction surface. We thought that since cottonseeds are ellipsoid, they would rotate to this position more often when sliding against a friction surface. The entrance end of the friction plates was tapered so that the seeds would gradually pick up the weight until the total normal force was on the seed.

The friction force measured during the time that the seed was moving under the part of the surface parallel to the force transducer was used in calculating the friction coefficient.

Results and Discussion

The analysis of variance of the entire experiment indicated highly significant interactions. Thus, comparison tests of statistical mean could not be conducted for each class.

The average coefficients for each factor when calculated over all the other factors are given in the following tabulation. The friction coefficients for the individual tests were in range of 0.0725 to 0.3625, with an overall of 0.204. In general, the class means do not exhibit a wide range. For example, the friction coefficient was 0.194 at 14 percent moisture and 0.215 at 10 percent. Obviously, the factors of velocity, normal force, and moisture content within the limits of this experiment did not appreciably influence the friction coefficients. In future tests one level of these factors could be chosen with little loss of information.

The plywood usually exhibited a lower friction coefficient than teflon or galvanized sheet metal. The reason for this could possibly be

Factor	*Coefficient*
Types of cottonseed:	
Gin run	0.222
Delinted	.185
Types of surface:	
Metal (galvanized)	.226
Plywood	.182
Teflon	.204
Moisture content (percent):[1]	
6	.202
10	.215
14	.194
Normal forces (pounds):	
2	.200
4	.210
6	.201
Velocity (inch per second):	
5	.197
10	.203
15	.211
Average, all factors	.204

[1] Wet basis.

[1] BICKERT, W. G., and BUELOW, F. H. KINETIC FRICTION OF GRAINS ON SURFACES. 1965. Amer. Soc. Agr. Engin. Paper No. 65-3231 presented at the annual meeting of Amer. Soc. Agr. Engin., Athens, Ga., 1965.

related to the cleaning procedure followed before each series of tests for the teflon and galvanized surfaces. The friction coefficients obtained from this investigation are lower than the 0.80 coefficient commonly recommended for cottonseed to metal.

These results indicate that a coefficient of 0.25 would probably be safe for gin-run cottonseed to metal. Using a lower friction coefficient would give a lower estimated power requirement for operating cottonseed conveyors.

Effects of Mechanical Damage, Storage Environment, and Specific Applied Treatments

Objectives of this phase are summarized as follows:

1. Develop methods of evaluating seed damage due to impact, cuts, and abrasion.
2. Determine the effect of method of processing to remove linters on the initial and subsequent viability and vigor of cottonseed with varying degrees of mechanical injury.
3. Determine the effects of mechanical damage on seed viability, free fatty acids, and vigor before and during storage under various conditions.
4. Determine the effects of application of fungicides and insecticides (systemic) on germination and emergence of seed with damaged seedcoats.
5. Determine the effect of mechanical damage on initiation and progress of deterioration in cottonseed during storage as assayed by the triphenyl tetrazolium chloride reaction.
6. Conduct standard germination tests and mechanical damage analyses on seed samples provided by the Agricultural and Biological Engineering Department at Mississippi State University, and the Texas and South Carolina Agricultural Experiment Stations.

Equipment and Procedures

The effects of level and severity of mechanical damage, storage environment, and specific applied treatments on quality of cottonseed were evaluated by the methods described in the following sections.

Incidence and Classification of Mechanical Damage

The incidence and severity of mechanical damage in seed lots were determined by soaking approximately one-fourth pound of gin-run, mechanically or flame-delinted, seed in concentrated sulfuric acid. The seed was held in the acid in a woven wire dipper (strainer). When the linters were adequately dissolved, the seeds were removed from the acid and washed thoroughly under a running tap water (2 minutes). They were then washed in a sodium carbonate solution for about 1 minute to further neutralize them. Finally, the seeds were dried in a small forced-air dryer (temperature 29° to 32° C.).

After the seeds were dried, they were processed in a South Dakota pneumatic laboratory blower, at an air setting of 80, to remove trash and immature seeds. The incidence and severity of mechanical damage were determined by visual examination of 200 randomly selected seeds. The seeds were classified into four categories:

Noncut—seed with completely intact seedcoats.

Pinhole damage—seed with only one or two small punctures in seedcoats.

Minor damage—seed with seedcoats cracked or cut but not severely; damage primarily to the chalazal end or on sides.

Major damage—seed with large cuts or ruptures in seedcoat, part of seedcoat missing, cotyledons often exposed, and damage to radicle end of seed.

Immature seed—seed with light tan or whitish seedcoat and shriveled. Immature seeds were not included among the damage categories, but they were evaluated in some of the studies. In those studies, all seeds that were lifted by the airstream in the South Dakota blower at an air opening setting of 80 were arbitrarily considered as immature.

The procedures used in evaluating mechanical damage are illustrated in figure 11.

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FIGURE 11.—Classification of seed according to incidence and severity of damage: *A*, Air separation of immature seed; *B*, visual classification of severity of damage; *C*, minor damage; *D*, major damage; *E*, noncut; *F*, pinhole damage.

Germination Tests

Germination tests were made in accordance with specifications given in the publication *Rules for Testing Seed* (*2*) except that four replications of 50 seeds (4 x 50) were used rather than 4 x 100 seeds (*2*)[2].

The seeds were planted in rolled towels (50 seeds per roll) and germinated in an automatically controlled germinator set at an alternating 20° to 30° C. temperature. Preliminary counts were made at 4 and 6 to 7 days after planting. Only normal seedlings with well-developed primary roots were counted and removed during preliminary evaluations. Final evaluations were made 10 days after planting and the tests were terminated. Criteria for evaluation of test results were those specified in the "Rules for Testing Seeds." Normal seedlings, which determined the percentage germination, were further classified into (1) normal seedlings with well-developed primary roots, and (2) normal seedlings with aborted or inhibited primary root development but with profuse secondary or lateral roots. Seedlings in the last category were termed secondary root seedlings and recorded separately. For all seedlings, however, percentage germination refers to the percentage of *both* types of normal seedlings.

Seedling classification criteria are illustrated in figure 12.

Cold Tests

In some studies cold tests were made in addition to standard germination tests to more rigorously evaluate mechanical damage or treatment effects. The cold test method used was similar to that used in the hybrid corn seed industry.

Soil was obtained from the top 2 inches in a field that had been previously planted to cotton. It was then screened to remove clods and plant refuse and thoroughly mixed with builder's sand in a 1:1 ratio. Plastic crispers, 7⁹⁄₁₆ by 10⅜ by 3¾ in., were used. In the tests, 1,500 grams of the soil-sand mixture were placed in each crisper. After the soil was firmed, 50 seeds were planted. An additional 100 grams of the sand-soil mixture were used to cover the seed about 1 inch. Water was then added to bring the media up to 60 percent of saturation. Tight-fitting lids were placed on the crispers and the tests were incubated at 13° C. for 72 hours. Following incubation, the tests were moved to a constant 30° C. environment for emergence.

The tests were interpreted after emergence (after 4 to 5 days at 30° C.). Normal emerged seedlings were counted and used to determine the emergence percentage of the cold test. Seedlings with no primary or secondary root development or less than one-half of the cotyledonary tissue or no development were classified as abnormal and not included in the emergence percentage. Each cold test consisted of three replicates of 50 seeds each. The cold test method is illustrated in figure 13.

Respiration

Respiration was measured in a Gilson Differential Respirometer.

Forty seeds were placed in a 100 milliliter reaction vessel, and 3.5 milliliters of distilled water were added. The system was operated at a constant 25° C. Carbon dioxide evolution and oxygen consumption were measured for a 30-minute period after 2, 4, 6, and 8 hours imbibition. Imbibition was considered to start at the time water was added to the flasks.

Free Fatty Acids

Free fatty acids were determined by the methods of the American Oil Chemists' Society (*1*). Regular analyses were made by the Barrow-Agee Company, Greenville, Miss. Microanalyses were made in the Seed Technology Laboratory.

Tetrazolium Tests

Tetrazolium tests were conducted according to the methods developed by Delouche and others (5). Seeds were soaked for 4 hours in 30° C. water. The seedcoat and nucellar membrane were removed and the embryo placed in a 0.5 percent solution of triphenyl tetrazolium chloride at 40° C. for 4 hours. The tetrazolium test assayed activity of dehydrogenase enzyme systems which are closely associated with viability. Areas in the embryo that did not reduce tetrazolium to its red insoluble form did not "stain" and were considered necrotic, while

[2] Italic numbers in parentheses refer to items listed in Literature Cited, p. 77.

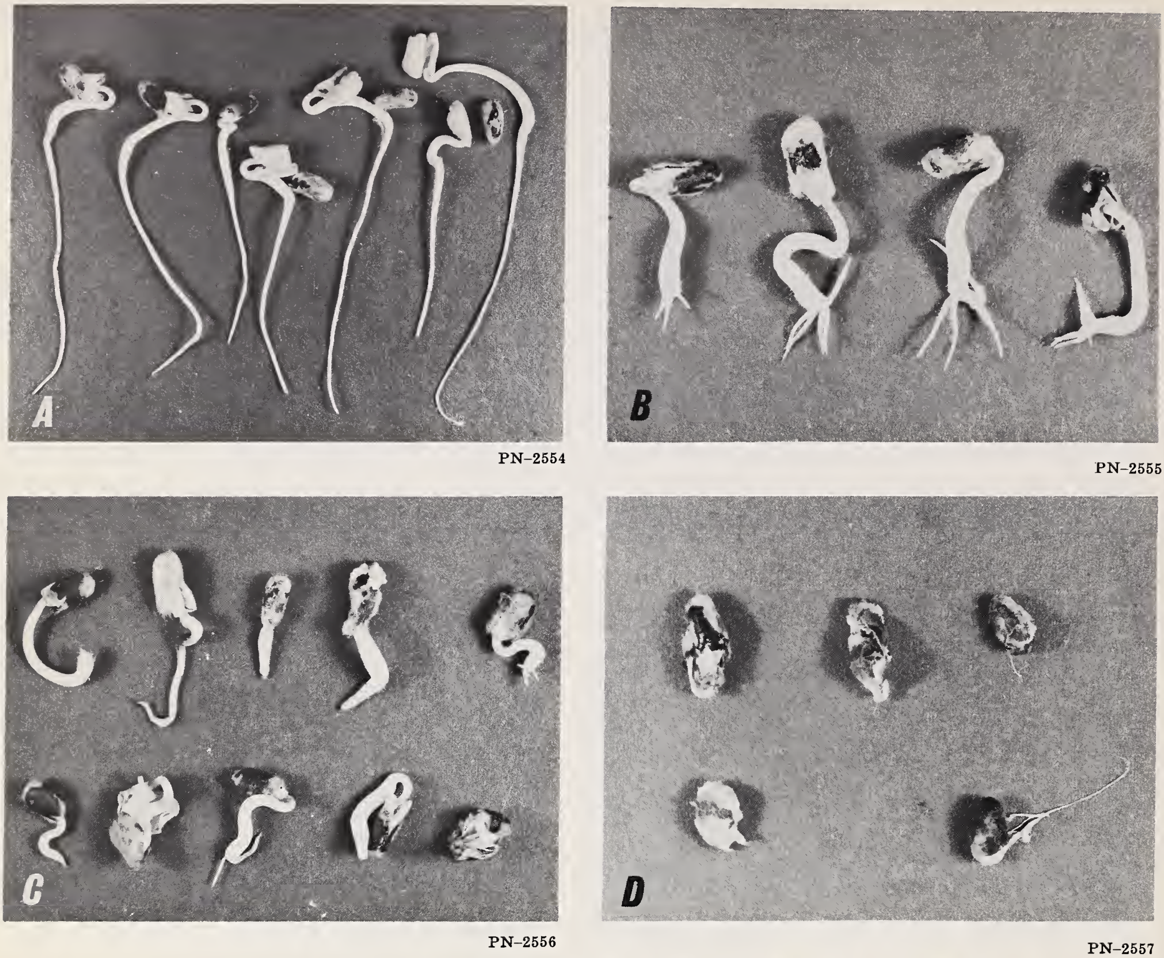


FIGURE 12.—Germination tests are interpreted as normal and abnormal seedlings and dead seed: *A*, normal seedlings with well-developed primary roots; *B*, normal seedlings with stubby primary roots, but vigorously developing secondary roots; *C*, abnormal seedlings; *D*, dead seeds.

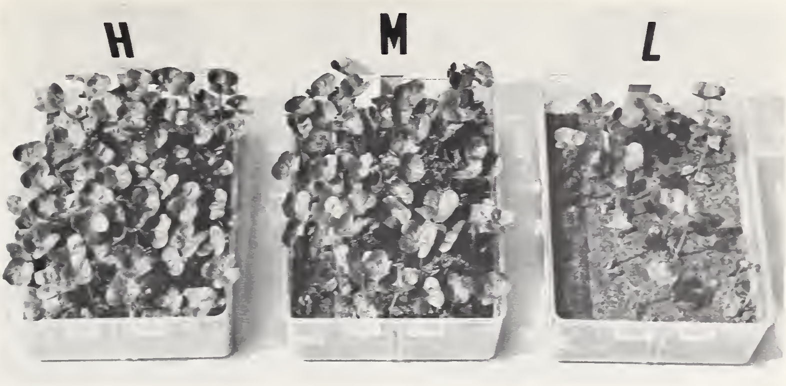
those that did reduce tetrazolium stained red and were considered as living tissue (fig. 14).

Seed Lots and Samples

A variety of seed lots and samples were used in the various studies. The relatively large seeds lots involved in the storage, fungicide-insecticide, and field emergence experiments were specially obtained and processed as described below. Smaller seed lots of sample size used in other studies were obtained from seed samples submitted for testing to the Mississippi State Seed Testing Laboratory by seed producers and companies.

Storage Studies

Experiment I.—Approximately one bale of Stoneville 7A cottonseed was handharvested at the Delta Branch Experiment Station in 1965. The seed cotton was divided into two parts. One part was ginned at a slow speed to obtain a low level of damaged seed; later analyses of this lot showed 4 percent of the seed was damaged. The other part was ginned at higher speeds with tight feed roll to produce a high level of damaged seed. Later analyses indicated that 47.5 percent of this secd was damaged. Both lots were ginned at the USDA Ginning Research Laboratory, Stoneville, Miss.



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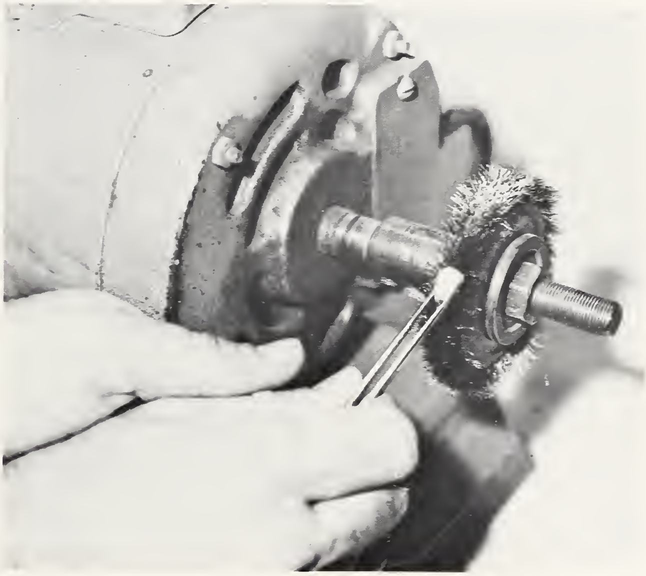

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FIGURE 13.—Cold test results: *Top, H*—high-quality seed, no mechanical damage, *M*, seed reduced in quality, minor mechanical damage, *L*, poor-quality seed, major mechanical damage; *Bottom*, mechanical removal of linters from gin-run seed for evaluation of mechanical damage.

The low- and high-damage-level lots were again subdivided into four equal parts of approximately 125 lb. each. These lots were processed as (1) gin-run seed, no further processing; (2) seed, flame delinted; (3) seed, acid delinted and neutralized with water; and (4) seed, acid delinted and neutralized with sodium carbonate in aqueous solution.

These lots were further divided into six lots for each processing method: Two with a low level and four with a high level of damaged seed. Percentage of seed in each lot by type of damage follow:

Lot No.	*Total damaged seed*	*Uncut*	*Pinhole*	*Minor*	*Major*
1	4.0	96.0	1.5	1.5	1.0
2	4.0	96.0	2.0	1.0	1.0
3	49.5	50.5	19.5	13.5	16.5
4	46.5	53.5	12.0	13.5	16.0
5	45.5	54.5	14.5	11.0	20.0
6	48.0	52.0	16.5	15.0	16.5

Parts of each lot were stored at 10° C. – 45 percent R.H.; 20° C. – 50 percent R.H.; 30° C. – 30 percent R.H.; and in open storage (uncontrolled). Samples were taken periodically for germination test over a 48-month period.

Experiment II.—Stoneville 213 cotton was hand harvested. Ginning speed and feed roll were adjusted to produce seed lots with three levels of mechanical damage: 3, 20, and 40 percent. The seeds from each damage level were divided into three equal parts and processed as (1) gin-run seed, no further processing; (2) seed, flame delinted, and (3) seed, acid delinted and neutralized with an aqueous sodium carbonate solution. Seeds from each processing method were again divided: one part was treated with the recommended rate of Ceresan L, a mercurial fungicide; the other part was not treated. These procedures produced 18 seed sublots for storage; three damage levels times three processing methods times two treatments.

Parts of each of the 18 sublots were placed in storage at 20° C. – 75 percent R.H., 30° C. – 75 percent R.H., and in open storage, uncontrolled. Periodically samples were drawn from storage for various tests and evaluations.

Seed Treatment-Damage Interaction Studies

Three different experiments were conducted to evaluate the effects of mechanical damage in combination with various seed treatments and methods of processing on storability and field emergence of cottonseed.

Experiment I.—Seeds of Stoneville 7A cottonseed obtained and processed as described in Storage Studies-experiment I were used. In this experiment, however, the seeds were taken before the final subdivision was made. Thus, eight seed lots were used: Two damage levels (4.0 and 47.5 percent) times four methods of processing (gin run, flame delinted, acid delinted-water neutralized, and acid delinted-sodium carbonate neutralized).

Seeds from each of the eight lots were treated with 0, 2, and 4 ounces of Ceresan L per 100 lb., and 0, 1, and 2 lb. of Thimet per 100 pounds of seed in all combinations. A randomized complete block design with a factorial arrangement of treatments was used for cold tests, standard germination tests, and field emergence evaluations.

Experiment II.—Acid-delinted seeds neutralized by both methods (water and sodium carbonate) from the Stoneville 7A source were visually classified into four damage classes: noncut, pinhole, minor, and major. Seeds within each damage class were treated with Ceresan L at rate of 0 and 2 oz./100 lb. and Thimet at rate of 0 and 1 lb./100 lb. in all combinations. Cold tests, standard germination tests, and field emergence evaluations were made. The design was a randomized complete block with a 2-by-2-by-2-by-4 factorial arrangement of treatments.

Experiment III.—Seeds from the acid-delinted—sodium carbonate neutralized sublot of Stoneville 213 described in Storage Studies-experiment II were used. Seeds were visually separated into four damage classes (noncut, pinhole, minor, major) and treated[3] as follows (recommended rates):

Ceresan L
Ceresan L + Demosan 65W
Ceresan L + Demosan 65W + Di-Syston (Technical)
Ceresan L + Demosan 65W + Thimet LC – 8
Ceresan L + Di-Syston (Technical)
Ceresan + Thimet LC – 8
Di-Syston (Technical)
Thimet LC — 8
No treatment

After treatment the seeds were stored under warehouse conditions (open-uncontrolled). Samples of seeds were taken at intervals and evaluated.

Seed Damage Evaluations in Commercial Lots

Approximately 1-pound sample of seeds were obtained from the Mississippi State Seed Testing Laboratory. These samples were all of 1968 production and had been submitted for germination tests. All were gin run, mechanically or flame delinted.

[3] Treatments were applied by E. I. Dupont de Nemours and Company, Wilmington, Del.

The samples were acid delinted by methods previously described, and a mechanical damage analysis was made. Sufficient seeds from each sample were then visually sorted into uncut, minor, and major damage classes for germination and cold tests. In these tests the pinhole damage class was included with the noncut class.

Miscellaneous Studies

Sources of seed and procedures used in several miscellaneous studies are described in the section where the results are presented and discussed.

Results and Discussion

Incidence of Mechanical Damage

A survey was made to determine the frequency of mechanical damage in lots of cottonseed planted by farmers. In cooperation with the Cooperative Extension Service, Mississippi State University, 738 samples were drawn from farmers' planter boxes in 43 Mississippi counties during the 1964 planting season (*7*). Additional samplings were made on a much smaller scale in the 1966–67 season and in 1968.

In the 1964 survey, nearly 30 percent of the samples had an incidence of mechanical damage of 10 percent or higher. Over all samples, damaged seed averaged 8.1 percent. Seed from the 1966 and 1967 crops (only 19 samples) averaged 14 percent damaged seed, 8 percent of which was severely damaged (major damage classification). In the 1968 seed, 15 percent was damaged of which 8 percent was severely damaged.

Averages do not always provide the clearest picture of a situation. A different perspective is provided in the ranges in damage level among the samples. In each year some samples evaluated were relatively free of damage (up to 7 percent) while others had as much as 37 percent total damage with 18 percent in the major damage category (1968 seed).

These data clearly show that high levels of mechanical damage are not inevitable and that in some way several seed lots were completely processed without sustaining any appreciable damage.

Influence of Mechanical Damage Level and Method of Processing on Storability

Experiment I.—Germinability of the seed was maintained quite well for 48 months in the 10° and 20° C. storage environments regardless of level of damage or method of processing.

Germinability of the seed stored at 30° C., however, began to decrease after only 12 months' storage (table 2). Initially, these decreases were among the seed at the high-damage level that had been acid delinted. By 18 months, the acid-delinted high-damage-level seed had decreased 10 to almost 12 percent from initial germination. Only one nonacid delinted lot (gin-run seed) showed a decrease in germination of the same order.

After 26 months' storage at 30° C., all lots began to decrease in germination. Reduction in germination among the high-damage-level lots, however, was much sooner and greater. These differences in rate of decrease in germination with time among low- and high-damage-level lots were not maintained beyond the 26-month period, after which germination of all lots tended to be quite similar with only minor variations.

Storage responses of the lots under uncontrolled conditions (open) were somewhat different (table 2). In almost every lot, the gin-run seed at both high- and low-damage levels appeared to deteriorate as rapidly, if not more rapidly, than the acid-delinted seed. Generally, high-damage-level seed began to decrease in germinability by 18 months, while the low-damage-level seed maintained viability through about 26 months' storage.

Storage data averages over all processing methods for the low- and high-damage-level lots are presented in table 3.

Decline in germination among the high-damage-level lots after 18 months' storage is evident. A comparable decline in germination of the low-damage-level lots did not occur until 30 months. On the average, low-damage-level seed continued to germinate higher than the high-damage-level seed until 48 months at which time there was little difference among the seed lots.

Experiment II.—The effects of mechanical damage level and processing method on storability of cottonseed were not as clear in this experiment as in the previous one. The data (tables 4–6) did not reveal any dramatic or

(Text continues on page 22.)

TABLE 2.—*Germination of cottonseed stored at 30° C. and under open (uncontrolled) conditions at different mechanical damage levels and different methods of processing*

Damage level and lot No.[1]	Initial germination	Percent germination (months)						
		6	12	18	26	30	40	48
				30° C. STORAGE				
Low level:								
1A	85.5	85.5	93.0	80.0	73.0	60.5	63.5	46.5
1B	85.0	91.0	97.5	90.5	86.0	79.5	61.0	30.5
1C	92.5	84.0	96.5	87.5	85.0	70.0	65.5	42.0
1D	88.0	82.5	96.5	87.5	85.0	77.0	71.0	56.0
High level:								
4A	80.5	90.5	94.5	84.5	67.0	43.0	62.5	30.0
4B	88.0	89.0	91.5	84.5	69.0	71.5	62.0	43.0
4C	84.0	80.5	90.5	72.5	71.5	59.5	61.5	37.0
4D	81.0	83.5	92.0	71.0	74.5	50.5	61.5	38.0
				OPEN STORAGE				
Low level:								
1A	85.5	89.5	97.5	80.5	76.0	63.5	64.5	38.5
1B	85.0	91.0	94.5	90.5	85.5	70.5	63.5	54.0
1C	92.5	94.0	96.5	89.0	85.0	80.5	70.5	43.5
1D	88.0	90.5	95.5	91.5	85.0	75.0	70.5	34.5
High level:								
4A	80.5	91.5	92.5	65.5	63.0	55.5	67.5	27.0
4B	88.0	90.5	95.5	88.0	79.0	80.0	72.5	57.5
4C	84.0	86.0	89.0	80.0	77.0	70.0	49.5	56.0
4D	81.0	87.5	91.5	79.0	80.0	62.0	57.0	33.0

[1] Low level = 4.0 percent damaged; high level = 46.5 percent damaged. Processing: A = gin run; B = flame delinted; C = acid delinted, water neutralized; D = acid delinted, sodium carbonate neutralized.

TABLE 3.—*Average germination of cottonseed at high- and low-mechanical damage levels for all methods of processing by specified storage conditions*

Damage level and storage condition[1]	Initial germ.	Percentage germination after specified storage periods (months)						
		6	12	18	26	30	40	48
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Low level:								
10° C	88.0	89.0	90.5	90.0	87.5	85.0	89.0	86.5
20° C	88.0	88.0	92.0	91.0	89.5	88.0	88.0	92.0
30° C	88.0	88.0	94.5	87.0	83.0	71.5	66.0	41.5
Open	88.0	91.5	95.0	87.5	84.0	74.0	68.0	40.0
High level:								
10° C	83.0	88.0	86.0	87.0	81.0	82.0	88.0	78.5
20° C	83.0	87.0	87.5	83.5	84.0	80.5	87.0	86.5
30° C	83.0	87.5	90.0	76.0	65.0	63.0	59.0	38.0
Open	83.0	88.0	91.0	78.0	71.0	62.0	59.0	37.0

[1] Low-damage level = 40 percent of seeds damaged; high level = 47.5 percent of seeds damaged.

TABLE 4.—*Standard germination of cottonseed (normal and secondary seedlings) at different mechanical damage levels, processed by different methods, stored at 20° C. - 75 percent R.H., with and without fungicide applied before storage*

Item	Initial germination	Germination after specified storage periods (months)									
		2	4	6	8	10	12	14	16	18	20
3-percent damage level	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
No fungicide applied:											
Gin run	96.0	92.5	93.5	95.0	93.0	91.5	88.5	81.0	74.5	70.0	46.0
Flame delinted	95.0	94.0	94.5	94.5	94.5	92.0	91.5	88.0	74.0	82.5	61.5
Acid delinted	95.5	92.5	96.5	96.0	93.0	94.5	89.5	87.5	75.0	80.5	58.0
Fungicide applied:[1]											
Gin run	96.5	95.5	94.0	94.0	93.5	95.0	84.5	76.5	78.0	87.5	53.0
Flame delinted	95.0	95.5	97.0	92.0	92.5	91.0	88.5	87.0	72.0	81.0	67.5
Acid delinted	94.5	96.0	94.0	94.0	94.0	96.0	85.5	88.0	85.0	80.5	68.0
20-percent damage level											
No fungicide applied:											
Gin run	95.5	96.0	93.5	92.5	89.0	89.5	87.5	72.0	71.0	65.5	51.0
Flame delinted	92.0	94.5	95.0	90.5	87.5	95.5	81.5	82.5	83.5	71.0	44.5
Acid delinted	94.0	90.0	92.0	91.0	90.0	90.0	85.5	85.5	71.0	80.5	52.5
Fungicide applied:[1]											
Gin run	98.0	97.0	96.0	90.5	92.5	86.5	89.0	81.0	81.5	84.0	63.0
Flame delinted	94.0	93.5	96.0	91.0	94.0	92.5	89.0	85.5	75.0	83.0	61.5
Acid delinted	95.5	94.0	94.0	91.5	89.5	88.5	76.5	85.5	73.0	86.5	53.5
40-percent damage level											
No fungicide applied:											
Gin run	90.0	91.0	93.0	92.5	86.0	92.0	82.5	85.0	75.0	68.0	53.5
Flame delinted	97.0	92.0	90.5	90.5	89.5	90.5	82.0	87.0	73.0	80.0	51.0
Acid delinted	91.5	90.0	83.0	85.5	85.0	87.0	78.5	82.5	74.0	71.0	49.0
Fungicide applied:[1]											
Gin run	94.0	92.0	93.0	94.0	90.5	92.0	81.5	82.0	79.0	83.0	58.0
Flame delinted	96.5	94.5	88.5	90.5	92.5	88.0	86.5	82.0	73.5	84.5	74.5
Acid delinted	93.5	87.0	89.0	90.0	86.5	84.0	80.5	77.5	75.5	75.5	66.0

[1] Ceresan.

TABLE 5—*Standard germination of cottonseed (normal and secondary seedlings) at different mechanical damage levels, processed by different methods, stored at 30° C. - 75 percent R.H., with and without fungicide applied before storage*

Item	Initial germination	Germination after specified storage periods (months)									
		1	2	3	4	5	6	7	8	9	10
3-percent damage level	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
No fungicide applied:											
Gin run	96.0	95.0	95.0	92.0	93.0	90.0	82.0	78.0	43.0	53.0	35.0
Flame delinted	95.0	95.0	94.0	93.0	95.0	94.5	89.5	88.5	80.0	64.5	55.5
Acid delinted	95.5	99.0	94.5	91.5	93.5	89.5	89.0	88.5	55.0	41.5	17.5
Fungicide applied:[1]											
Gin run	96.5	95.5	95.0	96.5	94.5	95.0	87.5	86.5	71.5	62.5	59.5
Flame delinted	95.0	96.0	95.5	96.5	96.0	92.0	87.5	88.5	75.0	57.5	52.0
Acid delinted	94.5	95.5	96.5	94.5	85.5	86.5	85.5	78.5	44.0	34.5	28.5
20-percent damage level											
No fungicide applied:											
Gin run	95.5	92.0	94.5	94.0	89.0	88.0	88.0	77.5	62.0	58.0	40.5
Flame delinted	92.0	97.0	96.0	92.5	95.0	94.0	91.0	88.5	78.5	66.5	38.5
Acid delinted	94.0	94.0	91.0	89.0	88.5	81.0	84.0	75.0	39.0	43.5	23.5
Fungicide applied:[1]											
Gin run	98.0	94.0	92.0	92.5	92.0	82.5	85.5	81.5	50.5	55.0	47.0
Flame delinted	94.0	93.5	96.0	93.5	96.0	87.5	90.5	86.0	75.5	66.0	49.0
Acid delinted	95.5	90.0	91.0	91.0	86.0	86.5	88.5	79.5	63.0	52.0	37.0
40-percent damage level											
No fungicide applied:											
Gin run	90.0	94.0	92.5	92.0	93.0	83.5	85.0	76.0	68.5	65.5	30.0
Flame delinted	97.0	96.5	94.0	92.0	92.0	90.5	87.5	83.0	84.0	75.0	57.0
Acid delinted	91.5	95.0	84.0	86.5	78.5	74.5	71.0	59.5	61.5	53.5	38.5
Fungicide applied:[1]											
Gin run	94.0	96.0	95.5	95.0	94.5	85.5	89.0	87.0	82.0	71.5	60.5
Flame delinted	96.5	92.5	90.5	89.5	91.5	89.0	80.5	79.5	65.0	66.5	46.5
Acid delinted	93.5	91.0	84.0	84.5	87.0	80.0	78.5	73.5	52.0	45.0	22.0

[1] Ceresan.

TABLE 6.—*Standard germination of cottonseed (normal and secondary seedlings) at differtnt mechanical damage levels, processed by different methods, stored in open storage, with and without fungicide applied before storage*

Item	Initial germination	Germination after specified storage periods (months)												
		3	6	9	12	15	18	21	24	27	30	33	36	39
3-percent damage level	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
No fungicide applied:														
Gin run	96.0	93.0	96.5	96.5	92.5	91.5	92.0	93.0	92.5	88.0	89.5	93.0	54.5	68.0
Flame delinted	95.5	96.0	95.0	98.0	95.5	88.5	91.5	96.5	87.0	93.5	90.0	91.5	68.5	72.0
Acid delinted	95.5	96.0	99.5	97.0	96.0	93.5	93.0	94.5	92.0	88.0	91.5	92.5	82.5	78.5
Fungicide applied:[1]														
Gin run	96.5	97.0	95.0	97.0	96.5	93.5	95.5	94.5	93.5	94.5	90.0	91.5	80.5	82.0
Flame delinted	95.0	94.0	96.0	95.0	94.0	90.0	94.5	93.5	89.0	91.0	90.5	86.0	84.0	73.5
Acid delinted	94.5	95.0	96.5	95.5	96.0	96.5	92.5	94.0	88.5	94.5	94.5	88.0	86.0	85.5
20-percent damage level														
No fungicide applied:														
Gin run	95.5	94.5	93.5	94.0	91.0	83.5	92.0	90.0	90.0	79.5	91.5	90.5	75.5	76.0
Flame delinted	92.0	92.5	96.5	96.5	95.0	90.0	94.5	92.0	88.5	94.5	91.0	91.5	65.5	82.0
Acid delinted	95.5	88.5	92.0	93.0	89.0	88.5	89.0	91.5	76.0	85.0	87.5	91.0	61.0	71.5
Fungicide applied:[1]														
Gin run	98.0	97.0	96.0	98.0	96.5	95.6	93.5	97.0	90.0	96.0	87.0	84.0	82.0	72.0
Flame delinted	94.0	95.0	94.0	93.5	84.5	93.0	94.0	96.5	92.5	94.5	85.5	93.5	85.0	72.5
Acid delinted	95.5	96.5	96.6	98.5	93.5	94.0	92.5	90.5	93.0	92.5	88.0	90.5	84.0	85.0
40-percent damage level														
No fungicide applied:														
Gin run	90.0	91.5	92.5	88.5	90.5	88.0	82.0	92.5	79.5	79.5	89.0	90.0	44.0	75.0
Flame delinted	97.0	97.0	92.5	95.0	92.0	91.5	89.5	93.0	84.0	89.0	86.5	91.5	76.5	81.0
Acid delinted	91.5	85.5	90.0	94.5	69.5	81.5	85.5	77.0	67.0	62.0	80.0	82.5	52.0	64.0
Fungicide applied:[1]														
Gin run	94.0	93.0	92.5	94.5	95.5	92.5	95.5	95.0	91.0	91.0	88.5	87.0	81.0	83.0
Flame delinted	96.5	93.5	93.0	92.0	83.0	95.5	93.0	89.0	90.5	93.0	85.5	80.5	77.0	79.5
Acid delinted	93.5	91.5	91.5	93.0	90.0	91.5	83.5	78.0	87.5	81.5	83.0	84.5	74.0	70.0

[1] Ceresan.

consistent differences in storage response as measured by the standard germination test among gin-run, flame-delinted, and acid-delinted seed with 3, 20, and 40 percent damage when stored at 20° C. – 75 percent R.H. for 20 months. Over all fungicide treatments, 40 percent-level seed, acid-delinted, began to deteriorate 2 to 4 months earlier than the other seed lots.

Under the 30° C. – 75 percent R.H. storage condition, the high-damage level acid-delinted seed began to decline in germination after 4 months' storage, while flame-delinted and gin-run seed with the same damage level maintained germination for 5 to 6 months. Acid-delinted seed regardless of damage level deteriorated more rapidly than gin-run or flame-delinted seed.

In open, uncontrolled, storage, germinability of all seed was maintained for 15 to 18 months. At that time high-damage level acid-delinted seed began to decline in germinability, while gin-run and flame-delinted high-damage-level seed did not begin to decline in germination until 27 to 30 months (table 6). Seed at the 3 percent and 20 percent damage level, regardless of method of processing or treatment, did not appreciably decline in germination until after 33 months' storage.

Responses did not differ much among the treated and nontreated seeds, except that untreated seeds at the high-damage level and acid delinted were erratic in germination.

Results from experiment II (as well as from experiment I) did not reveal any dramatic effects of level of mechanical damage or method of processing on germinative responses of cottonseed during storage. Germinability declined sooner and to a greater degree among seed lots at the high-damage level stored at 30° C. and under uncontrolled conditions. On the average, seed at the high-damage level (experiment I) began to decrease in germination after 18 months' storage at 30° C. and open condition, while seed at the low-damage level maintained viability quite well for 26 months. In experiment II, seed at the high-damage level (40 percent) that had been acid delinted began to lose germinability after 18 months' open storage, while the other seed lots maintained germinability for 30 to 33 months. At 30° C. – 75 percent R.H., acid-delinted seed at the high-damage level began to decrease in germinability after 4 months, while other seed lots did not show comparable decreases until 6 to 7 months.

On the basis of these results mechanical damage of cottonseed apparently reduces storage potential under open or high-temperature conditions (30° C.). The decreases in germinability, however, were not considerable and occurred under open condition only after 18 to 20 months. Acid delinting of high-damage-level seed further reduced storage potential.

To further evaluate the effects of level of mechanical damage and method of processing on maintenance of quality during storage, cold tests were made on the treated seed lots from experiment II at selected storage intervals. Responses to cold tests are presented in figures 14, 15, and 16.

Acid-delinted seed gave poorest cold test emergence regardless of level of damage. Further, emergence was closely related to level of mechanical damage—the higher the level of damage the lower was cold test emergence. Cold test responses of flame-delinted and gin-run seed were not appreciably influenced by level of

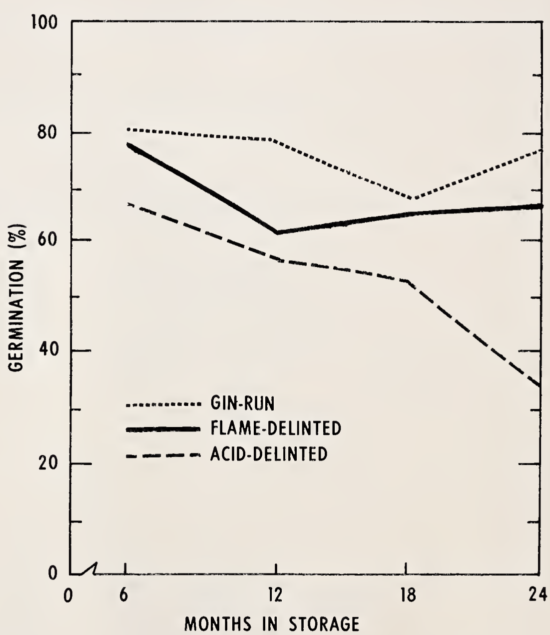


FIGURE 14.—Cold test germination percentages of low-damage level cottonseed (3 percent) processed by different methods after intervals of open storage.

damage. Overall lots and levels of seed damage, cold test emergence tended to decrease with time in storage. The lower quality of acid-delinted, moderate- and high-damage-level seeds was as evident before storage as at any time during storage. This finding indicates that the effects of mechanical damage are mostly immediate (after acid delinting) and that storage only gradually intensifies them.

Respiratory measurements of acid-delinted seed from different damage classes also indicated the detrimental effects of injury (table 7). During the early stages of imbibition (3 hours), the respiratory quotients (R.Q.) of

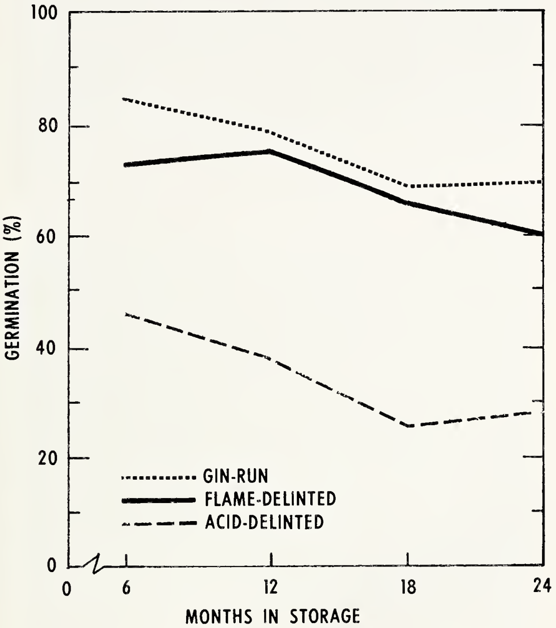


FIGURE 15.—Cold test germination precentages of medium-damage level cottonseed (20 percent) processed by different methods after intervals of open storage.

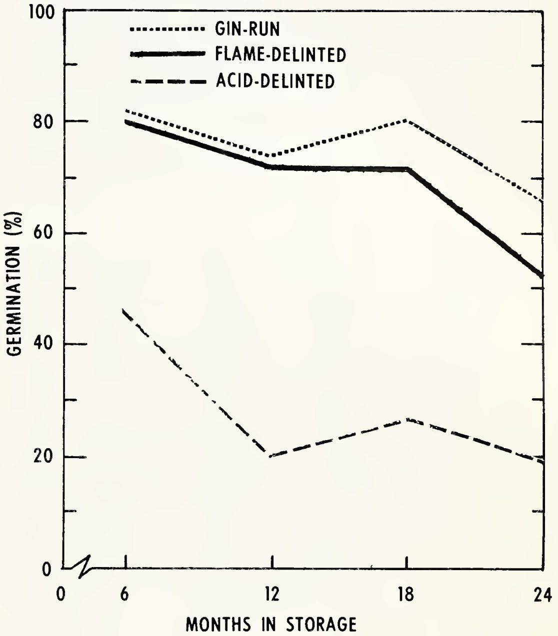


FIGURE 16.—Cold test germination percentages of high-damage level cottonseed (40 percent) processed by three methods after intervals of open storage.

TABLE 7.—*Respiration characteristics of different types of acid-delinted cottonseed after 2 years' storage at 7° C. – 50 percent R.H.*

Type of damage	Respiration after periods of imbibition [1]								
	3 hours			4 hours			6 hours		
	O_2	CO_2	R.Q.	O_2	CO_2	R.Q.	O_2	CO_2	R.Q.
Noncut	1.38	0.98	0.71	1.48	3.56	2.40	1.78	6.16	3.46
Pinhole	1.93	3.88	2.01	4.23	7.28	1.72	7.38	5.96	0.81
Minor	2.90	7.55	2.60	10.05	13.15	1.31	12.05	10.27	0.85
Major	2.18	7.26	3.33	5.55	10.73	1.93	4.23	2.60	0.61

[1] CO_2 O_2 expressed as microliters/seed/hour and respiratory quotients (R.Q.) as CO_2/O_2.

uncut, pinhole, and minor- and major-damaged seed were 0.71, 2.01, 2.60, and 3.33, respectively. Similar increases in the ration of carbon dioxide (CO_2) evolution to oxygen (O_2) consumption (CO_2/O_2) have been observed in other kinds of seed and interpreted as the result of impaired mitochondrial efficiency associated with deterioration. The higher O_2 consumption of the more severely damaged seed can be attributed to a faster rate of water absorption because of ruptured seedcoats.

Evaluation of deterioration of enzyme systems, that is, activity of the dehydrogenases as assayed by tetrazolium reaction, indicated that enzyme activity (and viability) decreased as the adversity of storage conditions increased. The site and severity of mechanical damage was closely related to the locus of initiation and progress of necrosis or enzyme deactivation. Necrosis began in embryonic tissue directly beneath damaged areas of the seedcoat and spread from these areas to surrounding tissue until, in some seeds, the entire embryo was necrotic (fig. 17). On the basis of staining patterns, apparently the immediate and latent effects of mechanical damage on deterioration, thus, also on germination,were directly related to site of injury. Damage to the chalazal end or side of the seed had less effect on germination than damage of similar severity to the radicle end of the seed.

Treatment of seeds before storage with a mercurical fungicide had little or no effect on percentages of germination until the late periods of storage. After 8 months at 30° C. – 75 percent R.H., 18 months at 20° C. – 75 percent R. H., and 36 months in open storage, percentages of germination were higher for treated than for untreated seeds overall levels of mechanical damage. The difference in germination was primarily due to a greater number of secondary root seedlings in the treated lots and reduction in abnormal seedlings. Apparently, these responses are related to the treatment of weakened seedlings from fungi during germination, permitting development of secondary roots. Untreated seed produced abnormal seedlings and did not germinate. Germination, however, had been greatly reduced in all seed lots by this time.

Increases in the percentage of secondary root seedlings were not related to level of mechanical damage or method of processing but appeared to be a stage in the progress of deterioration of cottonseed. Percentages of secondary root seedlings increased as germination began to decrease. A marked increase in secondary root seedlings was observed in germination tests after 8 months' storage at 30° C. – 75 percent R.H., and after 18 months at 20° C. – 75 percent R.H.

These increases either preceded or coincided with a rather sharp drop in germination and an increase in abnormal seedlings. Although similar trends were observed in seed in open storage, they were not as pronounced as in seed stored under constant high relative humidities. Germination of seed in open storage after 39 months, however, was roughly comparable to germination of seed after 8 months at 30° C. – 75 percent R.H. and 18 months at 20° C. – 75 percent R.H., so the marked increase in secondary seedlings might have been evident only in subsequent germination tests.

Observations from work on accelerated aging of cottonseed under high temperatures, 40° to 42° C., and 100 percent R.H., indicate a similar increase in secondary root seedlings just before or accompanying a decrease in germination. Thus, the marked increase in secondary root seedlings might possibly be associated with deterioration under constant high relative humidities during storage.

Generally, free fatty acids increased as time in storage increased, independent of damage level or method of processing. The only exception was acid-delinted at the 40 percent damage level, which tended to increase in free fat acidity faster than seed of other damage levels and methods of processing up to 30 months in storage. The tests were discontinued after this time because of a limited amount of seed remaining in the stored samples.

Free fat acidity did relate casually to germination percentage in that acid-delinted seed at the 40 percent damage level was the only lot of seed that showed a corresponding drop in germination when compared with other damage levels and methods of processing.

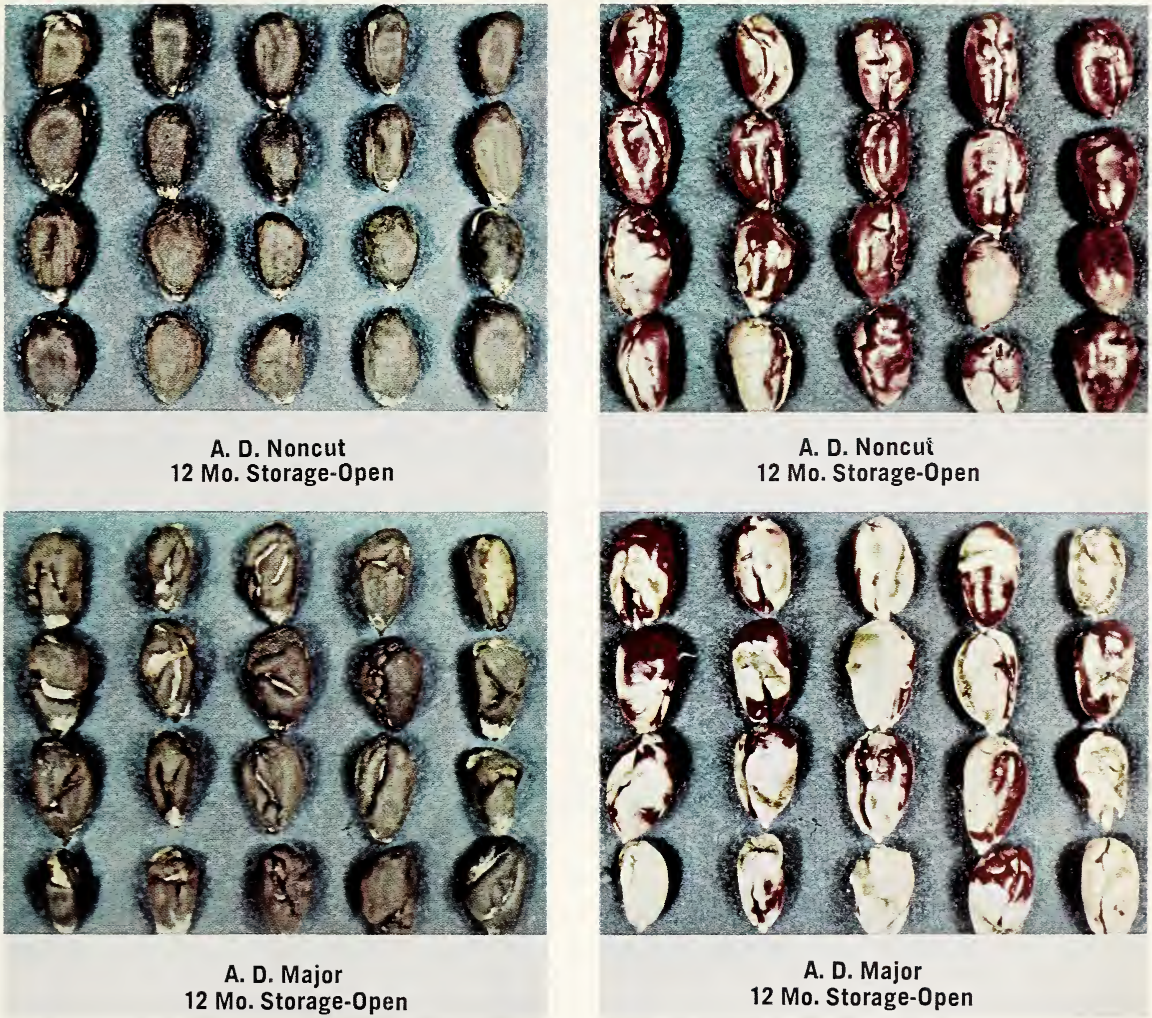


FIGURE 17.—Tetrazolium test reactions of acid-delinted seeds after 12 months open (warehouse) storage: *Top left*, seedcoat intact, no mechanical damage; *top right*, seedcoat removed, tetrazolium reaction shows no deterioration; *bottom left*, white areas are cut areas of seedcoat, major damage; *bottom right*, seedcoat removed, white areas are dead tissue, no reaction to tetrazolium.

Seed Treatment-Damage Interactions

Experiment I.—Field emergence and cold cold tests conducted on the same seed lots used in experiment I of Storage Studies, except that the two basic damage levels were not further subdivided, showed differences in performance among lots not readily apparent in germination test results (table 8 and 9).

Field emergence of seed without fungicide treatment did not reveal any differences between gin-run and flame-delinted seed regardless of damage level. Performance of acid-delinted seed at both high- and low-damage levels, however, was somewhat poorer.

Gin-run and flame-delinted seed at the high (47.5 percent) damaged level performed equally well or better than acid-delinted seed at the low-(4.0 percent) damage level. Acid-delinted seed at the high-damage level performed the poorest. Differences were also noted in responses of acid-delinted seed related to the method of neutralizing after acid delinting.

Application of a fungicide improved the performance of all lots of seed regardless of damage level or method of processing. However, the performance of the treated seed with regard to method of processing and damage level

changed. Acid-delinted seed at low-damage level gave highest emergence, while those at high level gave the lowest. Damage level among the gin-run and flame-delinted seed lots had no effect on emergence. Increasing the rate of fungicide caused little or no improvement in emergence. The field emergence tests indicated again that method of processing had more influence on performance than damage level.

Cold test responses were similar to those in the field (table 9). In untreated seed, those at the high-mechanical-damage level gave the lowest percentages of cold test emergence. Within the high-damage-level lots, the acid-delinted seed performed poorest. When the seed was treated, cold test emergence of all lots except the two acid-delinted, high-damage-level lots were above 86 percent.

The systemic insecticide Thimet was also applied to seed with different damage levels and processing methods. Results of germination tests are given in table 10.

Results of germination tests of cottonseed with and without Thimet treatment indicated that Thimet used alone usually reduced the germination. One exception was the low-damage level of acid-delinted seed at the 1-pound rate. The 2-pound rate of Thimet reduced germination over no Thimet in all tests and over the 1 pound rate in most of the tests. Again, the two exceptions were the low-damage levels of acid-delinted seed. This may be due to the amount of insecticide retained on or in the seed. The linters on gin-run and flame-delinted seed might have retained higher concentrations of insecticide than acid-delinted seed, while more insecticide might enter the seedcoat of the high-damage-level seed thereby damaging the embryo.

When Ceresan was used in combination with Thimet (table 11, data averaged overall mechanical damage levels), the same trends were evident. Application of Thimet generally reduced germination even when Ceresan was applied in combination.

Cold tests responses (table 12) indicated that the application of Thimet alone reduced seed performance. The application of Thimet magnified the lower quality of acid-delinted seed

TABLE 8.—*Field emergence of cottonseed with and without fungicide treatments at different levels of mechanical damage and methods of processing*[1]

Method of processing and damage level [2]	No treatment	Ceresan used per 100 pounds of seed	
		2 ounces	4 ounces
	Pct.	*Pct.*	*Pct.*
Gin run:			
High	B45.5a	A58.8ab	A B52.4 b
Low	B43.2ab	A64.4ab	A 59.1ab
Flame delinted:			
High	B43.9a	A62.7ab	A 62.9ab
Low	B40.5ab	A63.6ab	A B53.0 b
Acid delinted, neutralized with—			
Water:			
High	C33.5abc	A68.6a	B52.8 b
Low	B 8.9 d	A52.7 bc	A 45.6
Na_2CO_3:			
High	B30.5 bc	A70.9a	A 68.3a
Low	B26.4 c	A43.8 c	A 45.4 c

[1] Within each column any 2 means not followed by the same lowercase letter and within each row any 2 means not preceded by the same uppercase letter differ significantly at the 5-percent level of probability as judged by Duncan's New Multiple Range Test.

[2] High-damage level = 47.5 percent of seeds damaged; low-damage level = 4.0 percent of seeds damaged.

TABLE 9.—*Cold test emergence percentages of cottonseed at different mechanical damage levels and different methods of processing* [1]

Method of processing and damage level[1]	No treatment	Ceresan applied per 100 lb. of seed	
		2 oz.	4 oz
	Pct.	*Pct.*	*Pct.*
Gin run:			
Low	B76.4a	A94.1ab	A91.6 bc
High	B56.0 b	A91.9ab	A95.7ab
Flame delinted:			
Low	B73.0a	A90.6ab	A87.1 c
High	B52.5 b	A95.3a	A89.4 bc
Acid delinted, neutralized with—Water:			
Low	C60.9 b	B92.2ab	A 98.0a
High	C29.6 c	B58.9 c	A71.6
Na_2CO_3:			
Low	B57.4 b	A87.1 b	A94.3ab
High	B39.7 c	A72.2 c	A78.6 de

[1] Within each column any 2 means not followed by the same lowercase letter and within each row any 2 means not preceded by the same uppercase letter differ significantly at the 5-percent level of probability as judged by Duncan's New Multiple Range Test.

[2] High-damage level = 47.5 percent of seeds damaged; low-damage level = 4.0 percent of seeds damaged.

under cold test conditions. When no fungicide was applied, acid-delinted seed at both low- (4.0 percent) and high- (47.5 percent) -damage levels performed poorer than gin-run or flame-delinted seed regardless of damage. The addition of 2 and 4 ounces of Ceresan improved cold test response but acid-delinted seed at high-damage level treated with Thimet still gave the lowest responses. In almost all combinations, Thimet treatment reduced cold test emergence.

Field emergence tests of seed treated at the 1-pound rate of Thimet at two planting dates showed no appreciable reduction in emergence for the early (April 17) planting, but some reduction in emergence in the late (May 8) planting. Two pounds of Thimet per 100 pounds of seed reduced emergence at both planting dates in almost all tests.

Experiment II.—Seed obtained from the acid-delinted, high-damage level, Stoneville 7A lot, were visually classified and separated into four damage groups—noncut, pinhole, minor, and major. Seeds from each damage class were then treated with Ceresan and Thimet in several combinations. Results of germination and cold tests are presented in table 13.

Surprisingly, Thimet appeared to improve germination of damaged seed that had not been treated with Ceresan. This response is unexplainable but was also encountered in other experiments. On seed treated with Ceresan, Thimet treatment reduced germination in proportion to the severity of damage.

In cold tests, damaged untreated seed performed poorly. Pinhole-damaged seed without treatment emerged only 13 percent compared with 64 percent for undamaged seed. Emergence of the more severely damaged seed was near zero. Treating the seed with Ceresan greatly improved germination. Seeds without Thimet treatment, however, were improved much more than those with Thimet treatment, except for the minor- and major-damaged seed. Again, these responses are unexplainable.

Experiment III.—Acid-delinted seed from the high-damage-level (40 percent) lot of Stoneville 213 seed were visually sorted into noncut, pinhole, minor, and major damage classes. Seeds in

TABLE 10.—*Mean standard germination of cottonseed treated with insecticide (Thimet) at different levels of mechanical damage and methods of processing*[1]

Method of processing and damage level [2]	No treatment	Thimet used per 100 pounds seed	
		1 pound	2 pounds
	Pct.	*Pct.*	*Pct.*
Gin run:			
High	A93.1a	B81.7 bc	C55.3 cde
Low	A94.7a	B76.2 cd	C46.3 e
Flame delinted:			
High	A91.0ab	B75.8 cd	C55.0 cd
Low	A93.1a	B78.0 c	C56.2 c
Acid delinted, neutralized with—			
Water:			
High	A94.5a	B79.2 c	C49.0 d
Low	A93.3a	A89.2a	B64.4 b
Na_2CO_3:			
High	A88.5 bc	B71.3 d	C59.2 bc
Low	A85.7 c	A85.8ab	B72.0a e

[1] Within each column any 2 means not followed by the same lowercase letter and within each row any mean not preceded by the same uppercase letter differ significantly at the 5-percent level of probability as judged by Duncan's New Multiple Range Test.

[2] High-damage level = 47.5 percent of seeds damaged; low-damage level = 4.0 percent of seeds damaged.

TABLE 11.—*Standard germination of cottonseed with and without fungicide and insecticide treatments per 100 pounds of seeds by different methods of processing*[1]

Method of processing and rate of Thimet used	No Ceresan	Ceresan used per 100 pounds of seeds	
		2 ounces	4 ounces
	Pct.	*Pct.*	*Pct.*
Gin run:			
None used	A95.1a	A91.7 b	A94.8a
1 pound	A77.8 d	A76.2 c	A82.8 c
2 pounds	A61.5 e	B45.5 g	B45.4 f
Acid delinted, neutralized—			
With water:			
None used	B85.0 bc	A98.3a	A95.2a
1 pound	A92.8a	B75.7 c	B82.2 c
2 pounds	A57.8 e	A59.1 ef	A53.5 f
With Na_2CO_3:			
None used	B80.7 cd	A90.2 b	A89.7 b
1 pound	A84.0 cd	A B77.1 c	B75.5 cd
2 pounds	A66.1 e	A65.5 de	A65.7 e
Flame delinted:			
None used	A90.6ab	A94.5 b	A 90.8 ab
1 pound	A87.2 bc	B72.2 cd	B 69.9 de
2 pounds	A59.4 e	A53.2 fg	A 54.0 f

[1] Within each column any 2 means not followed by the same lowercase letter and within each row any mean not preceded by the same uppercase letter differ significantly at the 5-percent level of probability as judged by Duncan's New Multiple Range Test.

TABLE 12.—*Cold test emergence of cottonseed at low (4.0 percent) and high (47.5 percent) levels of mechanical damage and different methods of processing, by specific treatments with Ceresan and Thimet*[1]

Rate per 100 pounds of seed [2]	Gin run	Flame delinted	Acid delinted, neutralized with— Water	Acid delinted, neutralized with— Na_2CO_3
	Low-damage level			
	Pct.	*Pct.*	*Pct.*	*Pct.*
0–0	A76.4 b	A73.0 cd	B60.9 d	B57.4 d
0–1	AB44.9 de	BC37.7 f	CD31.6 e	DE25.0 e
0–2	A35.2 e	A28.3 f	B11.2 f	B 7.0 f
2–0	AB94.1a	AB90.6a	AB92.2 b	B87.1ab
2–1	A81.4 b	BC68.6 d	AB76.4 c	AB77.8 bc
2–2	A60.5 c	BC34.4 f	C29.3 e	C30.4 e
4–0	BE91.6a	CD87.1ab	A98.0a	AB94.3a
4–1	ABC78.0 b	AB79.8 bc	A82.3 c	CD68.3 cd
4–2	A53.3 cd	A54.5 e	CD20.4 ef	BC39.9 e
	High-damage level			
0–0	B56.0 c	B52.5 c	C39.7 c	C29.6 cd
0–1	BA38.9 de	A50.0 c	DE22.1 d	E20.3 d
0–2	A30.7 e	A28.6 d	C 1.6 e	BC6.0 e
2–0	AB91.9a	A95.3a	C72.2a	C58.9 b
2–1	A81.4 b	AB73.0 b	C57.6 b	BC66.8ab
2–2	B44.8 cd	BC36.0 d	D 4.1 e	C30.1 cd
4–0	AB95.7a	BC89.4a	DE78.6a	E71.6a
4–1	ABC78.5 b	BCD68.9 b	D58.4 b	BCD69.9ab
4–2	A56.0 c	A51.8 c	D14.7 d	B34.2 c

[1] Within each column, any 2 means not followed by the same lowercase letter and within each row any mean not preceded by the same uppercase letter differ significantly at the 5-percent level of probability as judged by Duncan's New Multiple Range Test.

[2] Ceresan (oz.)—Thimet (lb.)

each group were then treated with Ceresan L, Demosan 65W, Di-Syston (technical), and Thimet LC–8 at recommended rates in various combinations. The effects of severity of damage, treatments, and their interactions on several parameters of quality were evaluated after treatment (0 time) and at intervals during open storage over a 12-month period. Results of the study are summarized in figures 18 and 19.

Test measurements made on seed after treatment but before storage (0 time) were statistically analyzed. Subsequent measurements made during storage were not analyzed as initial trends continued and differences in responses were obvious.

Germination tests made on the seed before storage (0 time) did not reveal any difference in germinability of noncut seed treated with any chemical or combination of chemicals. This situation also prevailed for seed in the pinhole damage class. Minor damage seed germinated about 10 percent less than noncut seed over all treatments. Germination of seed treated with one or both fungicides (Ceresan or Demosan),

TABLE 13.—*Standard germination and cold test emergence of acid-delinted cottonseed with and without Ceresan and Thimet treatments, by class of mechanical damage*[1]

Thimet treatment and class of damage	No Ceresan applied	2 oz. Ceresan per 100 pounds of seed
Standard germination	*Pct.*	*Pct.*
No treatment:		
No mechanical damage	A98.2a	A97.9ab
Pinhole damage	B63.3 de	A98.9a
Minor damage	B56.0 e	A98.1ab
Major damage	B65.2 de	A97.6ab
1 pound Thimet:[2]		
No mechanical damage	A94.0 b	A94.8 b
Pinhole damage	A85.6 c	A86.2 c
Minor damage	A85.9 c	A81.1 c
Major damage	A71.6 d	A78.5 c
Cold test emergence		
No treatment:		
No mechanical damage	B64.20a	A93.90a
Pinhole damage	B13.30 c	A61.50 c
Minor damage	B 2.40 d	A12.30 f
Major damage	A 0.05 e	A 1.30 g
1 pound Thimet:[2]		
No mechanical damage	B32.10 b	A77.50 b
Pinhole damage	B12.90 c	A52.50 cd
Minor damage	B 0.03 e	A50.10 d
Major damage	B 0.00 e	A23.70 e

[1] Within each column, any 2 means not followed by the same lowercase letter and within each row any mean not preceded by the same uppercase letter differ at the 5-percent level of probability as judged by Duncan's New Multiple Range Test.

[2] Per 100 pounds of seed.

however, germinated 6 to 15 percent better than untreated seed. Seed treated with only Di-Syston or Thimet were lower in germination than seed treated only with Ceresan, but performed as well or better than untreated seed.

Major-damage-class seed germinated, overall treatments, 32 percent lower than noncut seed. Again, seed treated with fungicides germinated best. Seed treated with systemic insecticides alone gave lower germination but not any lower than untreated seed.

Greenhouse emergence responses were similar to those in the germination test. Differences in emergence among seed damage classes were considerable and the absence of a fungicide accentuated them. The beneficial effect of fungicides was clearly evident except for noncut seed. Performance of seed treated with either of the two systemic insecticides alone was equal to or better than that of untreated seed.

Cold test responses were similar to those previously discussed. The beneficial effect of Demosan was very evident.

In each of these three evaluations, either or both systemic insecticides when used alone sometimes produced a beneficial effect over the nontreatment control, and even over some of the other treatments and treatment combinations. For example, the Di-Syston- and Thimet-treated seed performed somewhat better than untreated seed in regular germination and greenhouse and cold tests.

These observations are similar to those made in some of the field studies. Apparently, on

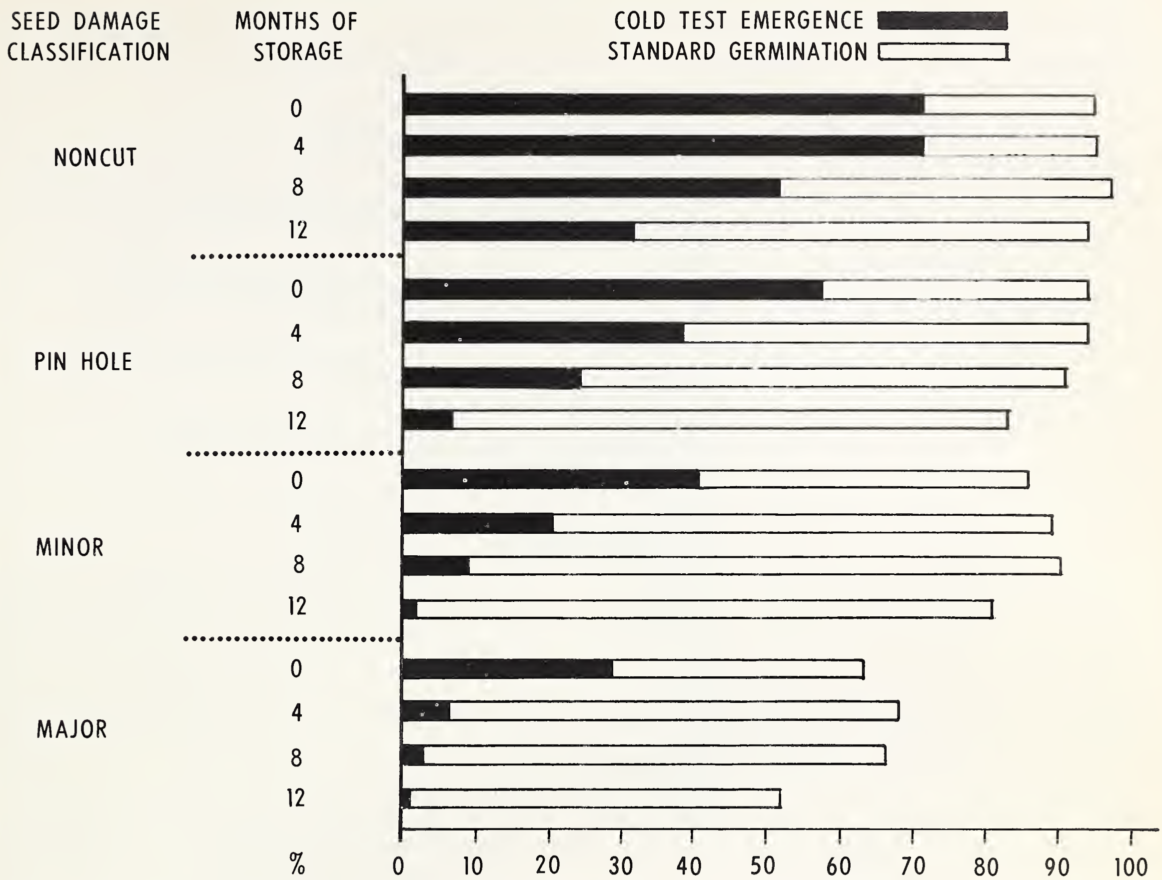


FIGURE 18.—Effects of seed damage level overall seed treatments on standard germination and cold test emergence of cottonseed after 0-, 4-, 8-, and 12-month warehouse storage.

some seed the systemic insecticides used here had a fungicidal or at least a fungistatic effect. However, evidence from other studies and experiences indicates that systemic insecticides applied as seed treatments tend to be harmful rather than helpful. Further work is needed to clarify these responses.

Germination percentages of noncut seed did not change over the 12-month period of storage under open conditions. Germination of seed with pinhole damage not treated with a fungicide dropped slightly during storage. Similar responses were obtained from seed in the minor- and major-damaged classes.

Percentages in cold test emergence of all damage classes of seed including noncut and all treatment combinations decreased as time in storage increased. The rapidity of decline in cold test emergence during storage was related to severity of damage. Uncut seed decreased in cold test reaction slowest, while major damage seed declined the fastest. Seeds treated with Demosan in combination with Ceresan provided the best protection to the seed under the stress of the cold test.

Comparative Storability of Gin-Run and Acid-Delinted Seed

A lot of gin-run seed was obtained from a commercial source and divided into two parts. One part was retained without further processing while the other was acid delinted. Both the gin-run and acid-delinted sublots were treated with Ceresan and Demosan at recommended rates. Samples from each sublot were then stored at 20° C. – 75 percent R.H., 30° C. – 75 percent R.H., and under open condition.

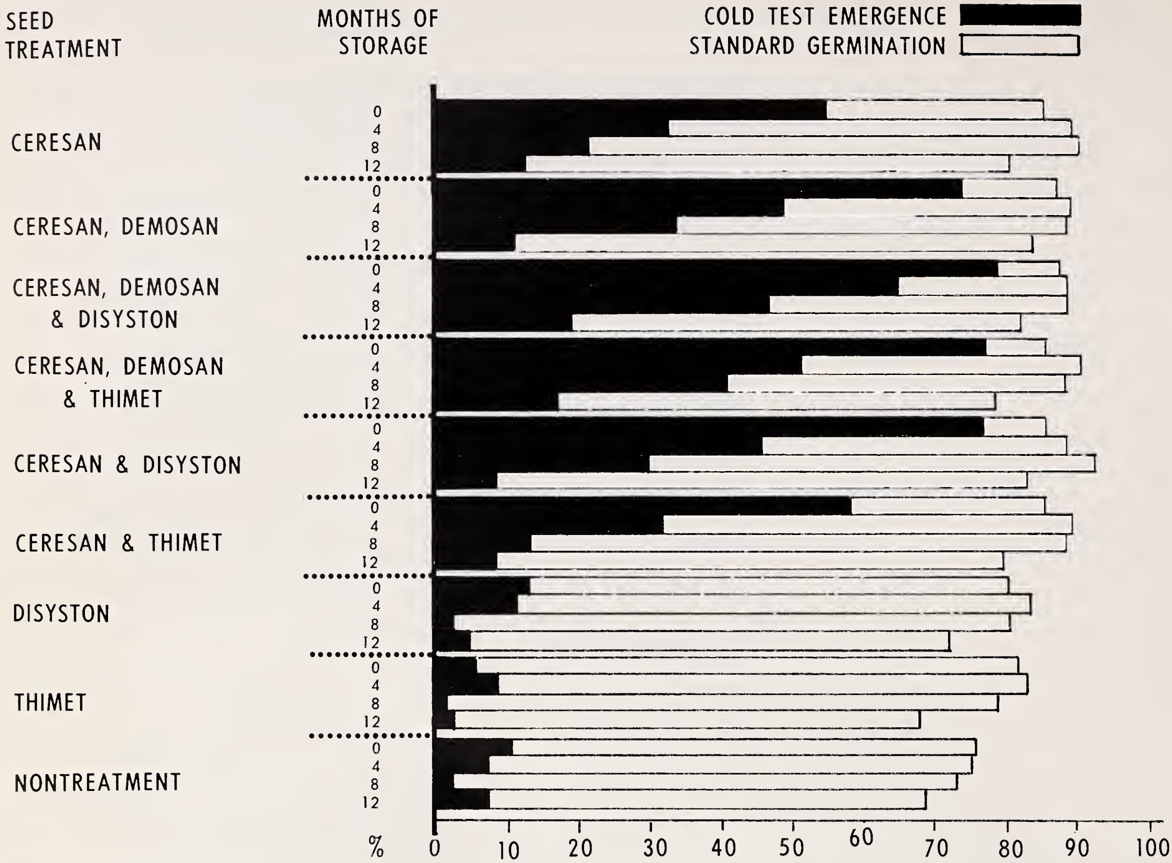


FIGURE 19.—Effects of seed treatments overall seed damage levels on standard germination and cold test emergence of cottonseed after 0-, 4-, 8-, and 12-month warehouse storage.

Germination and cold tests were made at monthly intervals over a 6-month period. Results are presented in table 14.

Acid delinting reduced storage life of the seed as indicated by the more rapid reduction in germination of acid-delinted seed stored at 20° C. – 75 percent R.H. and 30° C. – 75 percent R.H., and the consistently lower cold test responses of acid-delinted seed over time under all storage conditions.

Performance of Mechanically Damaged Seed in Commercial Seed Lots

In most of the studies discussed, one or, at most, two basic seed lots were obtained and then subdivided for different processing, chemical, or storage treatments in various combinations. This procedure was necessary to eliminate the confounding effect of source of seed on responses. Yet, at the same time these procedures limited observations to two basic seed lots (the Stoneville 7A and Stoneville 213 seed) that had not been handled in the usual commercial manner. As the studies progressed, some of the ambiguities in the data were thought to be related to the low number of basic lots observed.

To compensate for these limitations, 14 samples were drawn from commercial lots of seed. The lots represented an array of varieties and sources.

They were acid delinted, analyzed for mechanical damage and sorted into noncut (including pinhole), minor and major damage

TABLE 14.—*Percentage of gin-run and acid-delinted cottonseed germinating, stored under different conditions, by length of storage period*

Storage period (months)	Gin-run seed						Acid-delinted seed					
	Open		20° C.–75% R.H.		30° C.–75% R.H.		Open		20° C.–75% R.H.		30° C.–75% R.H.	
	Stand. germ.	Cold test	Stand. germ.	Cold test	Stand. germ.	Cold test	Stand. germ.	Cold test	Stand. germ.	Cold test	Stand. germ.	Cold test
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
None	84.5	70.0	84.5	70.0	84.5	70.0	87.5	71.0	87.5	71.0	87.5	71.0
1	85.0	70.0	89.5	74.0	84.0	77.0	85.0	66.6	81.5	77.0	81.5	59.0
2	87.5	86.7	88.0	77.0	84.0	39.6	88.0	76.6	89.5	74.0	78.0	29.0
3	87.5	79.6	90.5	74.3	72.5	9.3	88.0	75.3	85.0	70.0	66.5	8.3
4	76.5	78.0	76.5	76.6	35.5	6.7	80.0	86.3	77.5	67.2	20.5	1.7
5	83.5	71.0	83.0	65.0			89.5	69.6	73.0	70.6		
6	85.5	61.4	84.5	61.4			85.5	34.0	75.0	32.6		

classes, and immature seed. Germination tests were made on seed from each category and cold tests were made on uncut and minor damage class seed. Major-damaged seeds were not cold tested because seeds severly damaged do not emerge from the cold test regardless of treatments.

Table 15 presents data of two lots of seed with 11.5 and 13.5 percent damaged seed. Germination of the composite seed (before sorting) was quite low, 62 and 68 percent. Removing the damaged and immature seed greatly increased germination to 88 percent (noncut seed). Minor-damaged seed germinated 51 percent in both lots, while germination of major-damaged seed was negligible in both lots. Both lots had a high percentage (20 to 21 percent of immature seed. These seeds germinated 16 percent in lot 1 and 34 percent in lot 2. Cold test emergence of both minor- and major-damaged seed was negligible. An interesting aspect, however, was that the germinable "immature" seeds in lot 2 all survived in cold tests.

Table 16 presents mechanical damage analyses, germination, and cold tests results of various damage class seed from samples of 12 commercial lot of seeds.

Total damaged seed ranged from 8.5 to 26.5 percent among the lots for an average of 16.9 percent. Percentage of immature seed ranged from 1 to 11 percent for an average of more than 5 percent. Germination of the composite (unsorted) seed ranged from 70 to 82 percent. Removing the immature and damaged seed increased the germination by 2 to 20 percent with an average increase of 10 percent. Seed in the minor damage class germinated 12 percent less on the average than noncut seed, while major-damaged and immature seed germinated 50 and 73 percent, respectively, less than uncut seed.

Results of cold tests show even greater differences in quality between damaged and undamaged seed. Average cold test emergence of the composite seed was more than 65 percent, uncut seed 70 percent, and minor damage seed only about 22 percent.

These results indicate that the quality or germination of recently harvested cottonseed lots might be estimated from a mechanical damage analysis. On the average, three in four minor-damaged seeds were germinable, while only one in three major-damaged seed germinated. Additional analyses to determine percentage of immature seed would provide some information on probable cleaning loss. Much more work needs to be done before such procedures can be effectively used by cotton seedsmen. Particularly, many more lots need to be examined.

Separation of Mechanically Damaged Seed

Nineteen commercial-sized lots of acid-delinted cottonseed were processed over a Model 160 Oliver gravity separator with a 42- by 90-

TABLE 15.—*Effects of mechanical damage on the performance of cottonseed, 2 commercial seed lots*

Item	Lot 1 Composition	Lot 1 Stan. germ.	Lot 1 Cold test	Lot 2 Composition	Lot 2 Stan. germ.	Lot 2 Cold test
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Minor damage	5.5			3.0		
Major damage	8.0			8.5		
Total	13.5			11.5		
Immature	20.0			21.5		
Performance:						
Composite		67.5	54.5		62.0	55.5
Noncut		88.0	77.5		88.0	71.5
Minor		51.0	16.5		51.0	3.0
Major		4.0	0		12.0	4.5
Immature		16.0	6.5		34.0	35.0

inch rectangular deck.[4] After the separator was adjusted, samples of 5 pounds each were taken from 10 positions across the discharge end of the deck as follows: Sample *position 1* – first 3 inches of discharge edge from low side banking rail; *positions 2 to 9* – consecutively, each 4 inches farther up the discharge end from position 1; *position 10* – 4 inches from position 9 and 3 inches from uphill side banking rail. In gravity grading, density of the material graded increases from the low to the high side of the deck. Thus, seed of lowest density discharged at position 1, next lowest at position 2, and so on, and seed highest in density at position 10.

The distribution (in percentages) of mechanically damaged seed among the 10 separates from the 19 seed lots are shown in table 17. Although there were some inconsistencies, percentage of mechanical damage generally decreased from position 1 through positions 6 to 8, and then increased somewhat at positions 9 and 10. That is, percentage of mechanical damage decreased on the average as bulk density increased from 33 to about 45 lb./bu. and then increased slightly as density increased still higher.

[4] Seed were processed by Sawan Division, W. R. Grace and Company, Columbus, Miss.

Obviously, the gravity separator is not an efficient means of separating mechanically damaged cottonseed; however, mechanical damage can be substantially decreased by rigorous gravity grading.

Low-density seeds tend to be less mature and more deteriorated than the heavier seed. Such seed might sustain more mechanical damage because of softer seedcoats. The heaviest seeds (position 10) are also the largest seed; size might account for the general increase in mechanical damage above position 8. Other factors were probably also involved in these responses. Mechanically damaged seeds are often flattened or have cut sections of the seedcoat that protrude. Such "abnormalities" in shape reduce the terminal velocity of the seed, and they respond similarly to low-density seed on the deck of the gravity separator.

Several other methods of separating mechanically damaged cottonseed were given preliminary evaluation. The most promising of these methods appears to be the magnetic separator. Acid-delinted seeds are mixed with fine iron powder and a little water. They are then passed over a revolving magnetic drum (or drums). The iron powder lodges in cracks or ruptures in the seedcoat of damaged seeds and these seeds are attracted to the drum, separating from the stream. As very little powder clings to nondamaged seeds, they are not attracted to the drum. The principal limitations to this type of separation appear to be the capacity of existing magnetic separators and difficulties in mixing large quantities of seed, iron powder, and water. Time permitted only a very preliminary evaluation of the feasibility of using magnetic separators. Further work needs to be done.

X-Ray Analysis of Mechanical Damage

X-radiography of cottonseed was evaluated to determine its possible application as a rapid means of detecting mechanical damage. The machine used was the Faxitron 804 industrial tabletop X-ray. The system was adapted to use Polaroid-type 52 film which could be developed within 1 minute after exposure.

Only a certain percentage of mechanically damaged seed could be detected which can be attributed to orientation of the seed. Cuts in

TABLE 16.—*Percentage of mechanical damage in specified seed lots of acid-delinted cottonseed and effects of damage on germination and cold test emergence, 12 commercial seed lots*

Item	Lot No. 1	2	3	4	5	6	7	8	9	10	11	12	Average, all lots
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Composition of seed lot:													
Minor damage	1.1	4.0	8.5	5.5	5.5	8.0	6.5	6.5	5.0	13.5	12.5	14.5	7.6
Major damage	7.5	6.5	2.0	7.0	11.0	9.5	11.5	12.0	14.0	5.0	11.5	12.5	9.2
Total	8.5	10.5	10.5	12.5	16.5	17.5	17.5	18.5	19.5	20.5	24.0	26.5	16.9
Immature	5.5	11.0	1.5	9.0	3.5	4.0	7.0	2.0	1.0	7.0	7.0	3.0	5.1
Germination:													
Composite	78.5	70.5	82.0	75.5	80.5	76.5	71.0	83.5	67.5	82.5	70.0	79.5	76.5
Uncut	88.0	81.0	84.0	85.0	86.0	92.0	80.0	92.0	88.0	89.0	87.0	89.5	86.8
Increase	9.5	10.5	2.0	9.5	5.5	15.5	9.0	8.5	20.5	7.5	17.5	10.0	10.3
Minor damage	77.0	66.0	76.0	89.0	72.0	70.0	72.0	75.0	57.0	87.0	82.0	68.0	74.2
Major damage	34.0	40.0	43.0	50.0	35.0	37.0	16.0	45.0	21.0	37.0	47.0	33.0	36.5
Immature	18.0	2.0	13.0	3.0	9.0	9.0	14.0	17.0	8.0	25.0	21.0	21.0	13.3
Cold test emergence:													
Composite	75.0	78.0	64.5	64.5	66.5	67.5	62.0	73.0	39.5	62.5	63.5	65.0	65.0
Uncut	79.5	72.0	75.5	58.0	69.0	67.0	69.5	71.5	42.0	77.5	84.0	75.5	70.0
Minor	38.0	32.0	[1] 56.3	8.5	30.0	[1] 22.6	2.0	10.0	12.0	21.5	25.0	21.0	22.3

[1] Less than 200 seed planted.

the sides of the seed are detectable, but those on horizontal surfaces (top or bottom) are not unless damage is very great. Since cuts are detectable by their location on the seed in the path of X-rays, a factor for total damage could be developed. The efficiency of this factor will depend on how randomly cottonseed orient themselves on a flat surface, and how randomly damage is distributed over the seed surface.

X-ray analysis does appear to have some immediate application for rapidly estimating general quality of nondelinted cottonseed for immature or nonfilled seed. Such information would be useful in initial sorting of lots and in predicting cleaning loss.

Typical radiographs of cottonseed are reproduced in figure 20.

TABLE 17.—*Distribution (in percentage) of mechanically damaged cottonseed among separates obtained by gravity grading and as related to bulk density, 19 commercial seed lots*

Lot No.	Percentage of damage seed at sample position (gravity table)—									
	Light 1	2	3	4	5	6	7	8	9	Heavy 10
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
1	30	30	24	28	25	18	21	21	23	25
2	8	16	17	16	17	10	14	11	18	15
3	17	12	11	10	8	6	6	7	7	6
4	22	18	14	14	15	8	10	10	10	12
5	28	24	20	25	21	21	20	16	23	12
6	25	24	23	19	17	20	13	14	20	21
7	15	13	13	5	10	7	8	11	10	10
8	20	21	21	19	13	11	10	8	11	13
9	18	19	20	18	12	13	14	13	22	18
10	25	19	21	19	16	12	12	12	14	16
11	22	25	24	17	16	16	16	10	16	14
12	19	16	16	16	7	10	10	9	11	11
13	14	13	10	12	10	10	10	11	12	14
14	22	17	20	11	8	10	9	10	10	10
15	18	23	23	18	10	13	10	14	9	13
16	20	17	15	16	15	12	16	12	11	13
17	18	16	17	11	13	11	8	8	6	9
18	22	23	15	15	11	9	17	10	18	18
19	14	15	12	10	8	6	6	7	10	6
Average	20	19	18	16	13	12	12	11	14	13
Bulk density (lb./bu.)	33	40	41	42	44	45	45	46	46	47

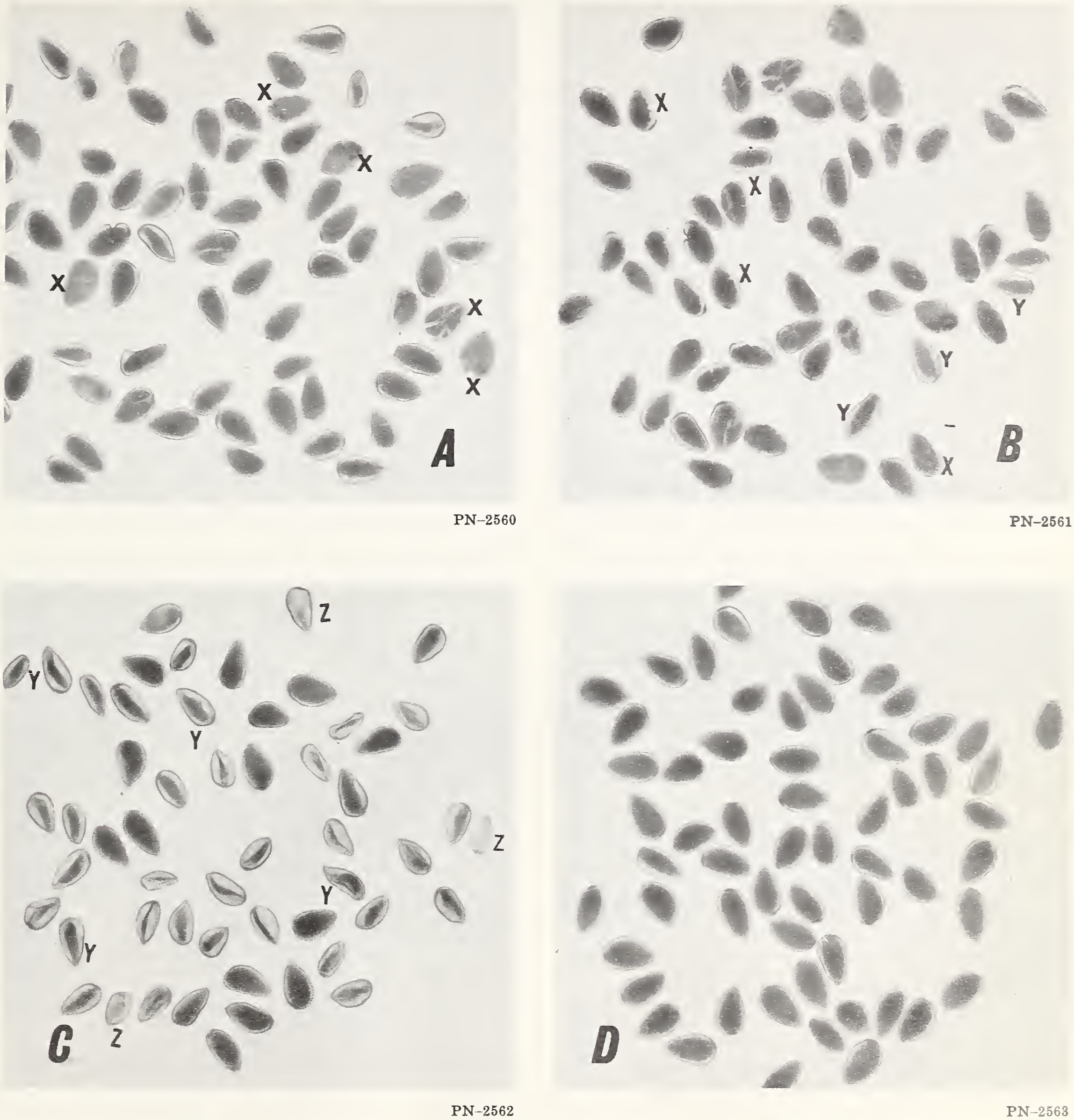


FIGURE 20.—X-radiographs of cottonseed: *A*, Mechanically damaged seeds—damage readily detectable in some seed (x); *B*, seed in low-density fraction from gravity table separation — badly damaged (x), immature seed (y); *C*, random sample of gin-run seed—immature seed (y), seed devoid of embryo (z); *D*, random sample of unprocessed acid-delinted seed.

Summary and Conclusions

Effects of Static Loading, Impact, and Abrasion

Cottonseeds are subjected to numerous high-velocity impacts and slowly applied forces in mechanical harvesting, ginning, and conveying equipment. The major objective of this study was to determine the effect of these types of forces on the germination and seedcoat damage of cottonseed.

The major variables considered were seed variety, seed moisture content, seed orientation, magnitude of slowly applied forces, and velocity of impact. Four varieties of cottonseed were used in the tests: Dixie King, Coker 100, Stoneville 213, and Deltapine Smooth Leaf. The seed moisture content ranged from 6 to 15 percent in approximately 2 percent intervals. The static forces were applied to the seeds in longitudinal and transverse positions. Impacts were made on the side, radicle end, and chalazal end of the seeds. The velocity of impact ranged from 3,000 to 8,000 f.p.m. in 1,000-foot intervals. Only one impact or force was applied to each seed.

The evaluation of the damage sustained by the seeds was based upon the percentage of germination and the percentage of seedcoat crackage.

A prediction equation of best fit was derived from the experimental data. A predicted germination was calculated for each velocity over all moisture contents, orientations, and varieties. The interpretations of the results were based upon the graphs derived from these values.

One test was conducted to determine the effect of more than one impact upon the percentage of seedcoat crackage. Seeds impacted three times at 3,000 f.p.m. velocity showed no increase in seedcoat crackage. However, at a 6,000 f.p.m. velocity the percentage of seedcoat crackage increased from 7 percent for one impact to 37.5 percent for three.

Another objective of the investigation was to determine the kinetic friction coefficient for cottonseed against metal, teflon, and plywood. The major variables included in the study were seed moisture content, velocity of the seed, type of seed (undelinted and delinted), and normal force. The coefficients obtained from the various combination of factors ranged from 0.0725 to 0.3625 with an overall average of 0.204.

From the results of these studies, the following conclusions were made:

1. The germination and the seedcoat of cottonseed sustained less damage when the seed moisture content ranged from 9 to 12 percent.

2. Germination is reduced more when impact occurs on the radicle end. Approximately 6,500 f.p.m. is the maximum velocity that seeds in the 9 to 12 percent moisture content range can be impacted without lowering the germination below the certification standard of 80 percent, assuming the initial germination was above 90 percent. For the seed moisture contents above and below the 9 to 12 percent range, the maximum velocity is approximately 4,500 f.p.m.

3. The seedcoat of cottonseeds is more susceptible to crackage when the impact occurs on the side. Minor seedcoat damage occurred with velocities up to 4,500 f.p.m., but above 5,000 f.p.m. the number of seedcoats broken with impact velocities increased rapidly.

4. With slowly applied loads, the germination was damaged more when the force was applied at the ends of the seeds. To maintain a germination of 80 percent, the maximum force cottonseeds at 4, 8, and 12 percent moisture could withstand with force applied at the ends was 18, 14, and 10 pounds per seed, respectively.

5. At energy absorption levels above 3 inch-ounces, slowly applied loads were more detrimental to seed germination than impact forces.

6. With impact velocities above 3,000 f.p.m., damage to seedcoats increased rapidly as the number of impacts increased.

7. The average kinetic friction coefficient of a single cottonseed against metal, teflon, and plywood was 0.204. Within the limits of this study, the different variables had little influence upon the friction coefficient.

Effects of Mechanical Damage, Storage Environment, and Specific Applied Treatments

Mechanical damage, a factor in practically all lots of cottonseed, seems to be increasing. As

many as 35 percent of the seed in some lots have damaged seedcoats. Over many lots, mechanical damage averaged about 14 percent of total 1967 and 1968 cottonseed produced in Mississippi.

In mechanically damaged seed, necrosis is initiated in embryonic tissue beneath cuts or fractures in the seedcoat.

As the incidence and severity of mechanical damage increases, germination is reduced and storage life is decreased somewhat.

The low quality of mechanically damaged seed is most apparent when the seeds are planted in the field or subjected to cold test conditions. Under these less than favorable conditions, mechanically damaged seed performs poorly regardless of treatment.

Detrimental effects of acid delinting appear to increase as level of mechanical damage increases. This response can be attributed to the effect of acid contacting the embryonic tissue through cuts or breaks in the seedcoat.

Acid delinting reduces the quality and storability of cottonseed as compared with other methods of processing. The extent of reduction appears to be related to quality of seed delinted. Low-quality seed are more affected by acid delinting than high-quality seed.

Seed treatment with an organic mercurial and overcoat fungicide markedly increased the percentage of normal seedlings produced by damaged seed in germination tests, but beneficial effects decreased as severity of damage decreased. These same responses also occurred in field and cold tests.

No conclusive evidence was obtained that systemic insecticides applied at proper rates have any detrimental effects on seed germination and field and cold test emergence. Some results do indicate that maximum benefits from seed-applied fungicides are not realized when systemic insecticides are applied in combination. Yet, other results show that systemic insecticides had a beneficial effect when applied in combination with fungicides.

Analyses of mechanically damaged seed from commercial seed lots indicate that, on the average, three in four minor-damaged seeds, one in three-major damaged seeds, and one in five immature seeds are germinable. Performance of both damaged and immature seed under stresses, such as those involved in the cold test, is very poor.

In gravity grading of cottonseed, mechanically damaged seed tend to be concentrated in the low and the highest density fractions. Gravity grading, however, is not a very efficient method of separating mechanically damaged seed from seed lots. The magnetic separator makes a fair separation of mechanically damaged from undamaged seed, but capacity of the machine is low and mixing seed with iron powder and water is difficult.

X-ray analyses of cottonseed can be used to rapidly assay seed lots for percentages of immature or empty seed. Some mechanical damage is detectable by X-ray analysis.

Part II. Cottonseed Quality as Affected by Harvesting Operations

Introduction

This phase of the research was conducted by the Agricultural Engineering Department, Clemson University, from 1965 through 1968. Emphasis was placed on determining the causes of poor quality in cottonseed in cotton harvested by spindle-type harvesters. Experiments were carried out on the Simpson Experiment Station at Pendleton, S.C., and in the laboratories of the Agricultural Engineering Department.

The objectives of the research were to determine the degree of damage to cottonseed quality at specific critical points in the mechanical harvester and to determine the influence of maturity and weathering on mechanical damage.

Review of Literature

Physical Characteristics of Cottonseed

Leahy (*12*) gave a detailed description of the cottonseed and its products. The cottonseed, being dicotyledonous, has two large cotyledons and, so-called, axial organs—the radicle, the hypocotyl, and the epicotyl. The cotyledons are folded around the radicle and over the top of the hypocotyl in the seedcoat.

During germination, the cotyledons and endosperm are the chief sources of nutrition for the developing seedling (*14*). If the hypocotyl is cracked or broken, the seedling cannot develop to maturity. If the cotyledons are cracked near the plumule, then the seed may germinate, but will be less vigorous because of the reduced nutrient supply. While the seedcoat is soft and flexible, the inner organs of the seed may be smashed without cracking the seedcoat.

Weathering and Storage Effects of Cottonseed Quality

Simpson and Stone (*21*) working at James Island, S.C., studied the influence of field conditions on the viability of cottonseed. Their findings included the following:

Approximately 4 days were required from the time bolls began to crack open until they were fluffed out.

During this opening period, the moisture content of the seed cotton was very high, varying from almost 60 percent on the first day after cracking down to 28 percent at the stage when handpickers would ordinarily harvest a boll.

Indications were that seed began to deteriorate in the field before harvesting. This deterioration seemed to be correlated with rains which prevented prompt drying of the seed cotton after the bolls began to open. Cotton which fluffed out in dry weather and was then rained on did not suffer as much seed deterioration as that which received rain during the opening stage.

Simpson reported in another article (*19*) that cottonseed had a period of dormancy after opening but that seed became viable at approximately 46 days after flowering. Helmer and Abdel-Al(*8*) found that cottonseed apparently reached maturity 46 days after anthesis (full bloom) or shortly after the bolls began to crack open.

Simpson (*19, 20*) and Pate and Duncan (*16*) have shown that good quality cottonseed will maintain its viability for extended periods with proper storage conditions. The longevity of cottonseed is drastically influenced by seed moisture and temperature.

Mechanical Damage to Seed

Damage to seed manifests itself in a lower rate of germination and decreased vigor of the seedlings. Justice (*11*) indicated that seedling

abnormality may be a secondary effect of fungus attack through lesions and breaks induced by severe mechanical damage. Research in the field of fungal-induced deterioration was reviewed by Christensen (*4*). Moore (*15*) stated that seed injuries, no matter how minor they may seem, are important in the resultant plant. Mechanical damage results in lowering the quality of cottonseed.

Harper, in a personal communication to Kirk, stated that mechanical injury will undoubtedly result in a rise in the free fatty acid content of cottonseed.[5] A rise in the free fatty acid content of cottonseed will reduce its germination ability and cause an accelerated rate of deterioration in storage (*21*). Simpson (*20*) found that cottonseed would not germinate with a free fatty acid content of 1.8 percent. Rusca and Gerdes (*17*) report similar findings for free fatty acid content versus germination.

Moore (*15*) explains that improper handling of seed may result in the lower part of the embryo and radicle being crushed. Harter (*6*) states that the epicotyl of snap beans was fractured just below the plumule by threshing machines resulting in a damage rate as high as 30 percent. Jones (*10*) reported that from 1 to 50 percent of alfalfa seed was damaged due to mechanical harvesting. This mechanical damage was closely related to a decrease in the germination ability of the seed. James (*9*) stated that seedcoat rupture or other damage in the vicinity of the embryo often results in abnormal germination, called "bald heads."

Zoerb and Hall (*22*) and Bilanski (*3*) have studied damage to seeds other than cottonseed. Using visible cracks as their criterion for damage, they determined the energy levels which resulted in damage for various moisture contents and orientations. Zoerb and Hall worked with gradually applied loads and low-velocity impacts.

General Procedure

The objectives were studied in six parts:

1. Field studies of picker damage
2. Study of damage in a 90° elbow
3. Damage vs. days after opening studies
4. Rate of boll opening studies
5. Laboratory studies on doffer damage
6. Laboratory studies on fan damage

Specific procedures are described separately under each test.

Test Descriptions and Results

Field Studies of Picker Damage

Procedure

These studies were conducted during 1965, 1967, and 1968. All tests were conducted with a picker in which the seed cotton was conveyed directly through a fan. In 1965 the tests were conducted with one fan speed (2,338 r.p.m.) and one variety of cotton (Carolina Queen). These tests were expanded in 1967 and 1968 to included two fan speeds, 1,807 and 2,338 r.p.m., and two varieties of cotton, Carolina Queen and Coker 413. The following treatments were included in the tests in the years indicated:

1. Handpicked check, 1965, 1967, and 1968.
2. Cotton picked with the front picker drum suction door open allowing cotton to fall directly on canvas sheet after doffing, 1965, 1967, and 1968.
3. Picked and conveyed through the ducts and fan but not allowed to strike basket-cleaning grates, fan speed 2,338 r.p.m. in 1965, 1967, and 1968 and 1,807 r.p.m. in 1967 and 1968.
4. Picked and conveyed normally through the entire picker system, fan speed, 2,338 r.p.m. in 1965, 1967, and 1968 and 1,807 r.p.m. in 1967 and 1968.

The tests were performed on short plot rows

[5] KIRK, I. W. STATIC ENERGY AND IMPACT VELOCITY REQUIREMENTS FOR COTTONSEED RUPTURE. 1961. (Unpublished master's thesis. Copy on file at Clemson University Library, Clemson, S.C.)

in the field (length of row, 10 feet in 1965 and 15 feet in 1967 and 1968). These rows yielded more than enough seed for germination and visual damage tests. The cotton was grown using conventional cultural practices. At defoliation the cotton was handpicked from the turn strips, and the stalks were pulled out by hand. In 1967 and 1968, the two varieties of cotton were grown in adjacent rows in the same field. During picking, the picker was set according to operator's manual specifications and operated at recommended speed. Fan speeds were changed during each replication by changing one pulley. Samples for seed cotton and cottonseed moisture content were taken just before harvest, except in 1965 when only samples for seed cotton moisture content were taken.

In 1965 and 1968, harvest conditions were considered ideal and the crop was estimated to be 80 to 85 percent open. An early freeze on October 16, 1967, however, severely damaged those seeds which had a high-moisture content. Harvesting the 1967 crop was delayed until February 1968, making the results not indicative of a normal year. All samples including the handpicked check were ginned on a small six-saw laboratory gin.

Results

The major results of the picker damage tests appear in table 18. The results show that the mechanical harvester injures cottonseed both by reducing germination and by creating visible seedcoat cracking. During picking and doffing, the quality of the seed is slightly reduced but by far the greatest damage occurs in the pneumatic conveying system. At the high fan speed (2,338 r.p.m.), the percentage of germination may be expected to be reduced approximately 2 to 4 percent, while the percentage of seeds containing visible cracks in the seedcoat range from 12 to 20 percent, after traversing the pneumatic conveying system.

The damage at the high speed is from 2 to 3 times as great as the damage at the low speed (1,807 r.p.m.). Harvest conditions in all 3 years were such that the moisture contents of seed were very close to that of seed cotton.

Study of Cottonseed Damage In a 90° Elbow

Procedure

This study of cottonseed damage in a 90° elbow is reported in detail by Christenbury.[6] A laboratory simulation of an elbow similar to that used on commercial cotton pickers was constructed for conveying the seed cotton.

Air velocities within the duct ranged from 4,000 to 14,000 f.p.m. using 2,000 f.p.m. intervals. The elbow was constructed of Plexiglas so that high-speed movies could be taken of the cotton as it passed through. From the movie film, the path of the seed cotton and the impact velocity were obtained. The elbow was placed approximately 72 inches from a large "catch box" where the flow of seed cotton was stopped by a burlap screen. This screen prevented further damage to the seed and the catch box was sufficiently large so that the cotton was not picked up again by suction from the external fan. Air velocities in the duct were measured between the elbow and the catch box, 61 inches downstream from the elbow, with a hot-wire anemometer.

The degree of weathering was considered an important attribute related to seed damage. Cotton bolls were tagged in the field the day they opened to measure the effects of weathering on seed cotton. Four days were allowed for the boll to fluff out after cracking open. Cotton harvested on the fifth day was considered to be weathered one day. Weathering periods included in the experiment were 1, 2, 4, 10, 16, 32, and 64 days.

The experiment included six velocities and seven weathering periods with each velocity, replicated four times. A split-plot statistical design was used in setting up the test.

The seed cotton (variety Carolina Queen) was hand harvested from one large field requiring no subdivision. The bulk cotton for each

[6] CHRISTENBURY, G. D. QUALITY OF COTTONSEED FROM SEED COTTON PNEUMATICALLY CONVEYED THROUGH A SINGLE ELBOW. 1966. (Unpublished master's thesis. Copy on file at Clemson University Library, Clemson, S.C.)

TABLE 18.—*Percentage of seed germinating (normal plus secondary roots) and percentage having visible cracks resulting from picker damage, by specified treatment, gin-run cottonseed, 1965, 1967, and 1968*[1]

Variety of cotton and year	Type of treatment					
	HP	PDO	S_1PG	S_2PG	S_1ST	S_2ST
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Germination of seeds						
Carolina Queen cotton:						
1965	93.7a	90.1 b		87.2 c		86.9 c
1967	16.9a	16.2a	21.1a	17.0a	17.9a	14.4a
1968	86.6 cde	86.8 cde	87.7abcde	84.2 def	85.9 cdef	81.7 f
Coker 413 cotton:						
1965						
1967	28.0a	26.7a	24.3a	24.6a	25.0a	17.2a
1968	90.6ab	91.3a	87.8abcd	88.2abcde	89.7abc	83.7 ef
Seeds having visible cracks						
Carolina Queen cotton:						
1965	0.1a	6.3 b		19.3 c		20.8 c
1967	6.1 e	12.9 cd	27.9 b	37.8ab	14.4 c	44.6a
1968	0.4 g	4.1 de	4.1 de	12.3 b	3.9 de	7.7 c
Coker 413 cotton:						
1965						
1967	1.2 f	7.4 de	14.6 c	37.3ab	14.9 c	43.0a
1968	1.2 fg	2.7 ef	7.4 c	20.7a	6.4 cd	17.4a

[1] Percentages followed by the same letter or letters are not significantly different at the 0.05-percent level.

[2] Treatments as follows:

HP = handpicked

PDO = doffed on canvas without going through conveying system.

S_1PG = going through doffing, elbows, and fan at speed of 1,807 r.p.m. but not striking basket-cleaning grates.

S_2PG = same treatment as above except fan speed set at 2,338 r.p.m.

S_1ST = straight through complete system at fan speed of 1,807 r.p.m.

S_2ST = same treatment as above except fan speed set at 2,338 r.p.m.

maturity level was brought into the laboratory where it was divided into four lots. Each lot contained enough samples for each velocity treatment plus enough cotton for a check sample which was not conveyed through the elbow.

Following completion of the conveyance part of the test, the seed cotton was stored for approximately 1 month before being ginned. Samples were ginned on a six-saw laboratory gin at a slow rate. The cottonseed was then tested as in the picker damage test.

Figure 21 gives a graphical representation of rainfall as related to weathering of the cotton samples during this test. Although some rainfall was experienced, 1965 was considered an excellent harvesting year.

Results

Study of high-speed movies revealed that the seed cotton traveled in practically a straight line until it impacted aginst the elbow wall. After impact, locks of cotton remained in contact with the elbow until they had passed through the bend. Air velocity in the duct was measured with no cotton in the system, as stated previously, 61 inches downstream from the elbow. Velocity of the seed cotton was measured over the last 10 inches before it impacted against the elbow.

The velocity of the seed cotton was less than that of measured air velocity but was linearly related to it. Velocity of seed cotton was related to the air velocity by the following equation:

$$Vs.\,c. = -776 + 0.678\,Va;$$

where

$Vs.\,c.$ = seed cotton velocity (f.p.m.), and
Va = air velocity (f.p.m.).

This equation applies only for the system used in that particular study. The relationship of

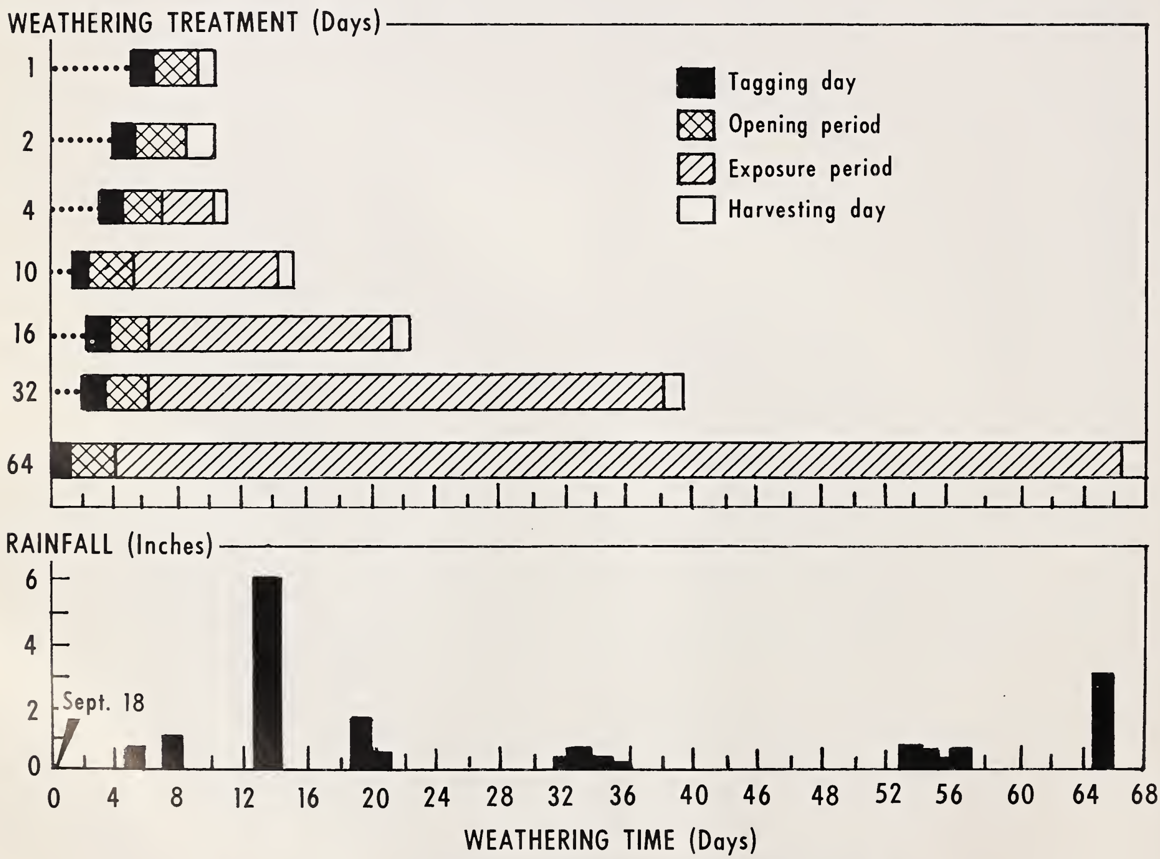


FIGURE 21.—Rainfall on cotton from data of tagging until harvest, 1965.

velocity of seed cotton to air would depend upon where the velocity of air was measured, the configuration of the ducts, and the rate of flow of cotton through the duct. Future references will be to actual velocities of seed cotton and the values will be rounded to the nearest 50 f.p.m.

Seed cotton impaction against the wall of a Plexiglas elbow at a velocity of 1,950 f.p.m. did not result in a reduction in germination percentage. Weathered samples 1-day old were reduced drastically in germination percentage for impact velocities of 3,300 f.p.m. and above (fig. 22). The 2-day weathered treatments showed reductions of approximately 10 and 15 percent in germination percentage for impact velocities of 7,350 and 8,700 f.p.m. For all other stages of weathering, the germination reductions due to impact were surprisingly small at all velocities.

As expected, the proportion of seeds having visible cracks in the seedcoat increased with both weathering and impact velocity (fig. 23). At air velocities above 10,000 f.p.m. (impact velocity, 6,000 f.p.m.), the percentage of cracked seedcoats increased drastically. A comparison of data on percentage of germination and percentage of cracked seedcoats shows that many seeds with cracked seedcoats apparently still germinate. At impact velocities of seed cotton below 6,000 f.p.m., the percentage of seeds

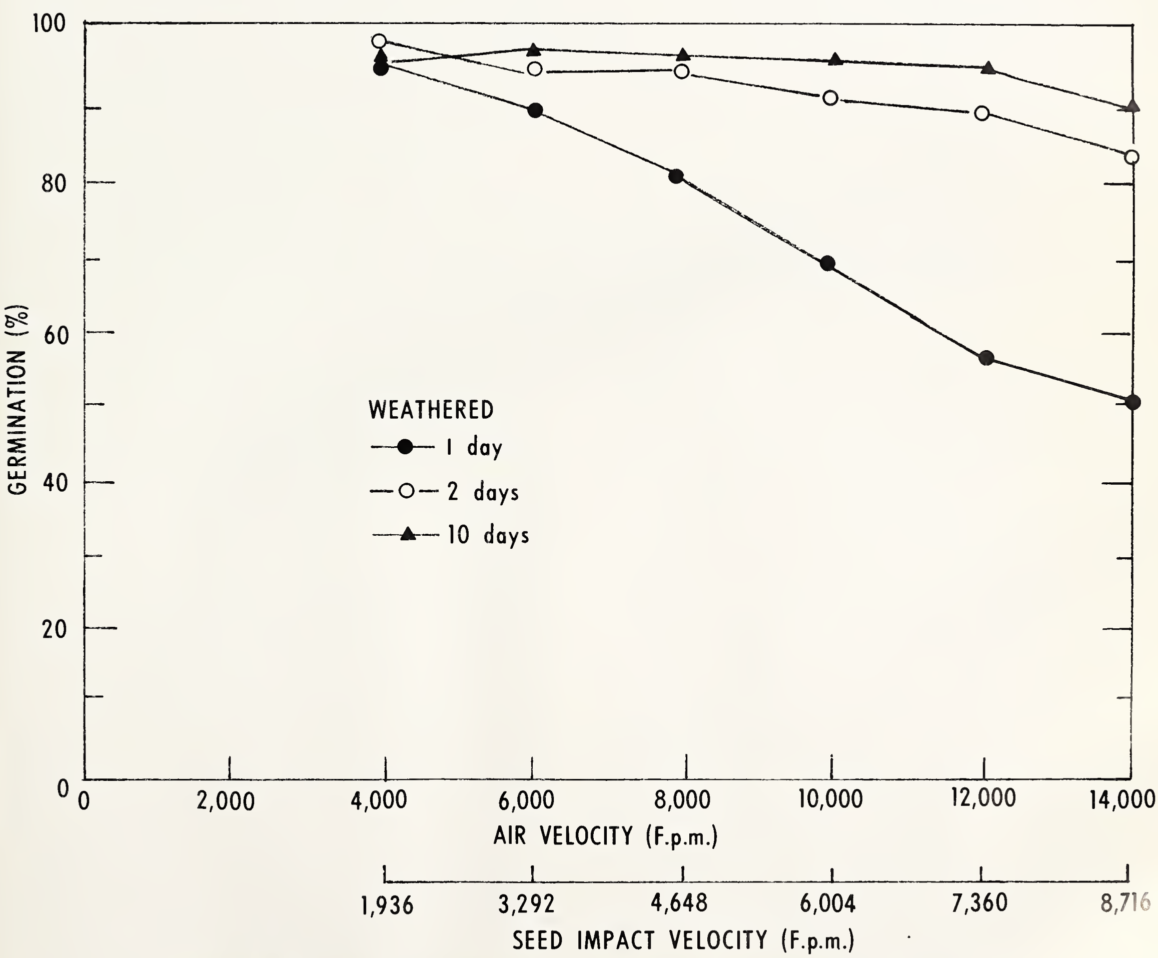


FIGURE 22.—Effect of impact velocity in a 90° elbow on germination of cottonseed.

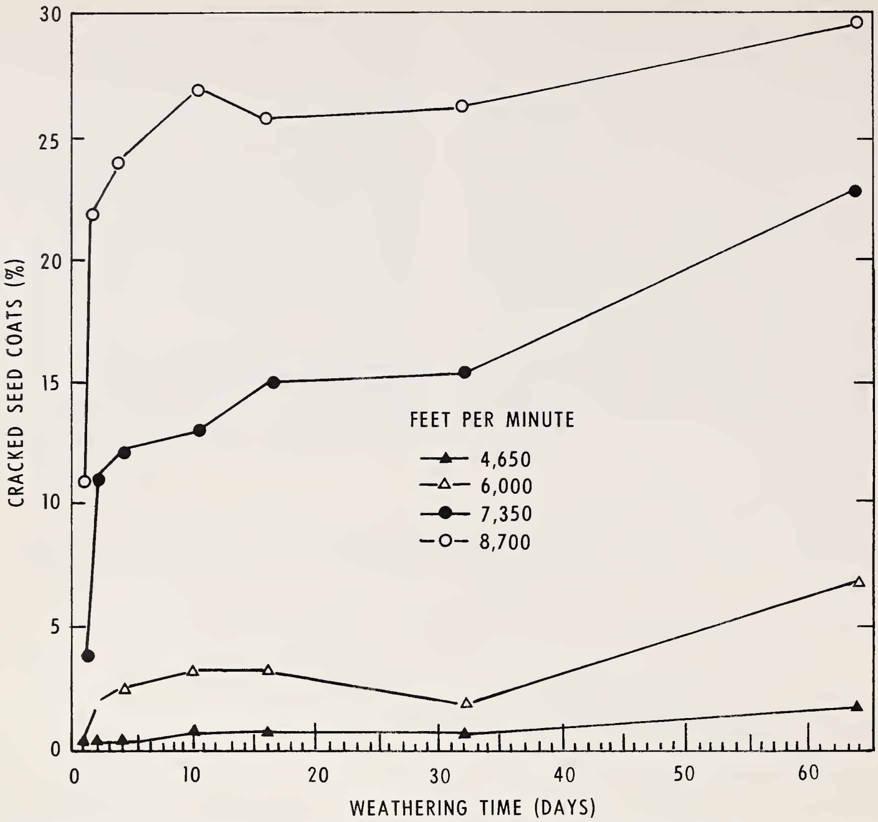


FIGURE 23.—Percentage of seed having cracked seedcoats versus weathering time at specified impact velocities.

cracked was very small (below 2 percent) for all stages of weathering. Although impact velocities in commercial pickers are unknown, the air velocity was measured for one picker operating without cotton in the ducts and at recommended speed with a fan speed of 2,338 r.p.m. The air velocity was approximately 6,500 f.p.m. Since the seed cotton velocity is expected to be considerably below this velocity, the results of this study appear to be that a single impact in the elbows of the tested picker is highly unlikely to crack seeds. The effects of multiple impacts were not determined.

The Carolina Queen cottonseed that was handpicked, not subjected to impact, and ginned on a small laboratory gin had a germination rate of 96 to 98 percent for up to 32 days of weathering in the field. Between 32 and 64 days of weathering, germination of gin-run cottonseed dropped to approximately 90 percent. Germination of acid-delinted seed was slightly higher than the gin-run seed; for up to 32 days weathering, it was approximately 99 to 100 percent and for the 64-day weathering treatment, 95 percent.

One significant point emphasized by this study is the extent to which germination percentages are reduced in newly fluffed bolls. Figure 22 shows that cottonseed with 1- and 2-day weathering treatments suffered marked reductions in germination at the higher conveying velocities. The seed cotton moisture contents for the various weathering periods ranged from 27 percent for 1-day weathering to a low of 5.75 percent at 16 days, and back up to 10.5 percent at 64 days. It would have been preferable to have the seed moisture contents for these samples but, unfortunately, samples were not taken for these determinations. The seed moisture contents were expected to be higher than

the seed cotton moisture contents of 27 percent, 11.75 percent, and 10.25 percent for the 1-, 2-, and 4-day weathering periods.

Damage Versus Days After Boll Opening

Procedure

In the study of damage occurring in a 90° elbow, Christenbury (see reference listed in footnote 6) found that percentage of germination was reduced considerably for his 1- and 2-day weathering treatments.

In his study, cotton bolls were tagged when the carpels were separated less than a half inch at the tips. Four days were then allowed for the bolls to fluff out before the weathering treatment started. Cotton receiving 1-day treatment was harvested on the fifth day. Based upon field observations, it was thought that a spindle picker would harvest bolls that had been open less time than Christenbury's 1-day-weathered bolls. Because these newly opened bolls were apparently very susceptible to damage in that lower percentages germinated, determining the relationship between percentage of damage due to a standard impact and stage of opening for the early period soon after initial boll opening was considered essential.

The standard impact test selected was conveyance through a 90° elbow at an air velocity of 10,000 f.p.m., which would give an impact velocity of approximately 6,000 f.p.m. This velocity resulted in approximately a 30-percent germination reduction in Christenbury's 1-day weathered treatment in 1965. Also, it caused a small amount of seed cracking (approximately 3 percent) in the 1965 experiment for the more weathered bolls. In the damage test with a spindle picker in 1965, approximately 20 percent of the seed was cracked. Thus, the standard damage test of 10,000 f.p.m. was thought to be severe enough to cause germination reductions with susceptible seeds but not as severe as might be encountered in some components of a commercial picker.

These studies were conducted during the 1966 and 1967 seasons. Data from the 1967 season, however, were of limited value because of an early freeze that damaged the seed crop.

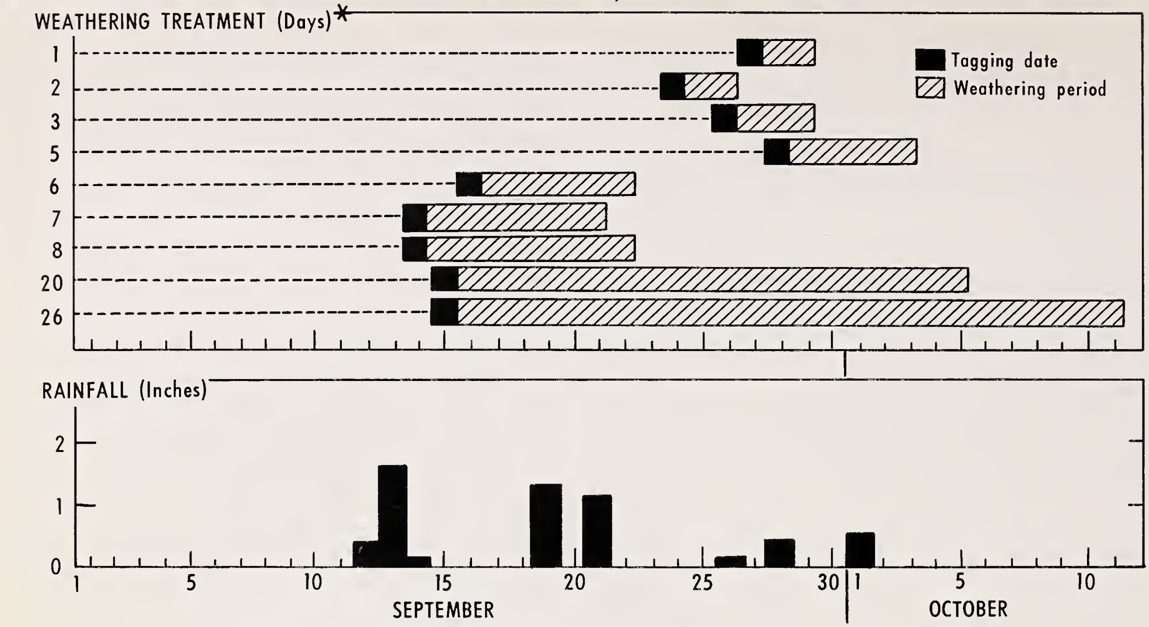
Bolls were tagged in the field after boll cracking but before the carpels were separated a half inch at the tips. After a specified waiting period, the bolls were picked and subjected to the standard damage test. Nine treatments investigated in 1966 were 1, 2, 3, 5, 6, 7, 8, 20, and 26 days between tagging and harvesting and five treatments in 1967, 3, 5, 6, 7, and 12 days. The tagging and harvesting days for 1966 and 1967 are shown graphically in figures 24 and 25.

In all, 600 bolls were tagged to be used in the treatments. Each treatment was replicated six times. These bolls were harvested, pooled into a single batch, and taken to the laboratory. Here, the batch was weighed and divided randomly into 12 equal samples for the six replications and a check. A replication consisted of a test sample conveyed through a 90° elbow at 10,000 f.p.m. air velocity; the check sample was not conveyed.

Four locks of cotton were selected randomly for each replication for seed moisture content tests. Seeds from these locks were hand delinted, and moisture content was measured by the oven method.

As a part of this study, tests were made on cottonseed selected at random from all samples to determine the energy and force required to rupture the seed in a slow compression test. These tests were conducted to provide additional data on the relationship between damage susceptibility and seed moisture content for the high-moisture ranges.

At the same time that the locks were being selected for moisture content determinations, two additional locks were selected to provide seed for the slow compression tests. From 14 to 18 seeds were hand delinted from these two locks and stored for a short time in seamless tin cans until the rupture tests. An Instron Universal Testing Instrument ruptured the seed and recorded the forces required to cause rupture. The seeds were placed between two large, flat steel surfaces with a side orientation. The top steel surface, attached to the crosshead of the instrument, moved down on the seed at a rate of 1 cm./min., or 0.394 in./min. The recording instrument was calibrated to give a full scale deflection of 20 kg. and forces were read to the nearest 100 g.



*BECAUSE OF RAIN ON THE SCHEDULED HARVEST DATE, THE ONE-DAY WEATHERING TREATMENT WAS HARVESTED ONE DAY LATE. THE AMOUNT OF DRYING DURING THE TWO-DAY PERIOD WAS MORE NEARLY TYPICAL OF ONE-DAY WEATHERING BECAUSE OF LOW-DRYING POTENTIAL.

FIGURE 24.—Rainfall on cotton from date of tagging until harvest, 1966.

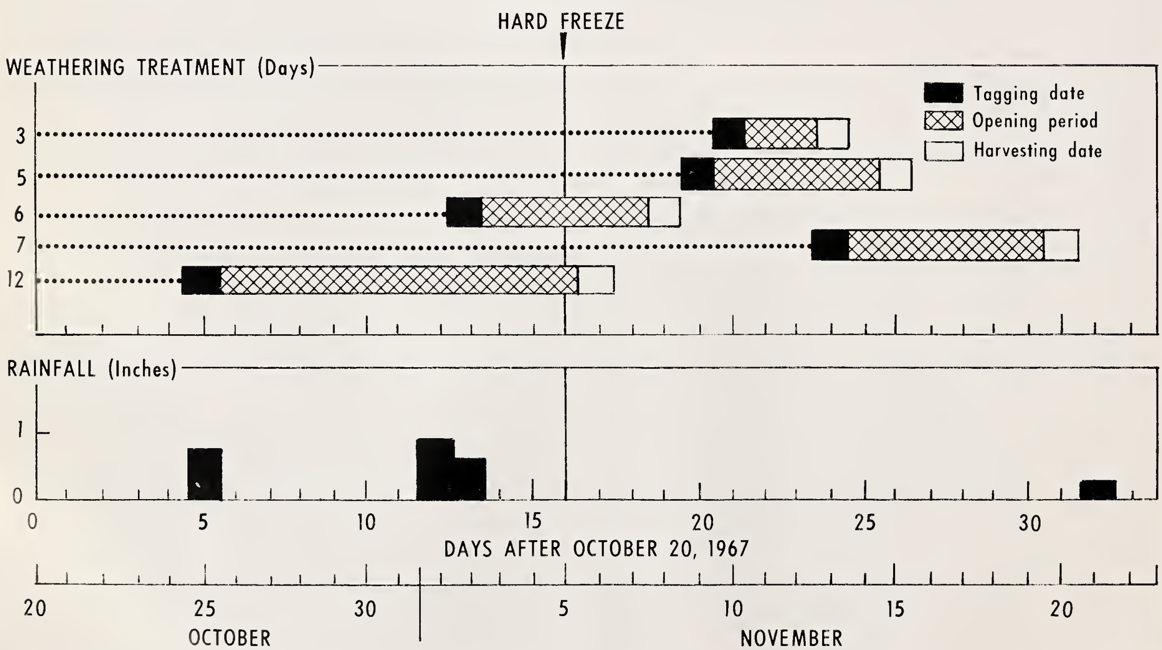


FIGURE 25.—Rainfall data, tagging dates, and weathering periods for 1967 test of weathering time versus damage susceptibility.

Results

Figures 26 and 27 show the variation of germination and visible damage with days after opening and seed moisture content. These data are from the 1966 tests. Impact of seed cotton against a 90° Plexiglas elbow at approximately 6,000 f.p.m. resulted in germination reductions of cottonseed when the seed moisture content was 14.4 percent or more. Some reductions were as high as 19 percent. At cottonseed moisture contents of approximately 8 percent, 4 percent of the seedcoats were cracked by impact. Cottonseed at moisture contents of approximately 12 to 13 percent had no appreciable reduction in germination or cracking by impact in the 90° elbow. Thus, these results indicate that the effect of impact on cottonseed is determined to a large extent by seed moisture content.

In addition, these studies showed that the rate of boll opening is markedly influenced by weather conditions after the bolls have cracked open at the tips. Seed that received rainfall during the opening period opened at a slower rate and appeared to be more susceptible to reduction in germination by impact than seed which opened under rapid drying conditions, without rain, even though the seed was at the same moisture content at the time of impact. This observation that rainfall is detrimental to seed during the opening stage is supported by the conclusion of Simpson and Stone (*21*) in 1935. They stated that cotton which fluffed out in dry weather and was then rained on did not

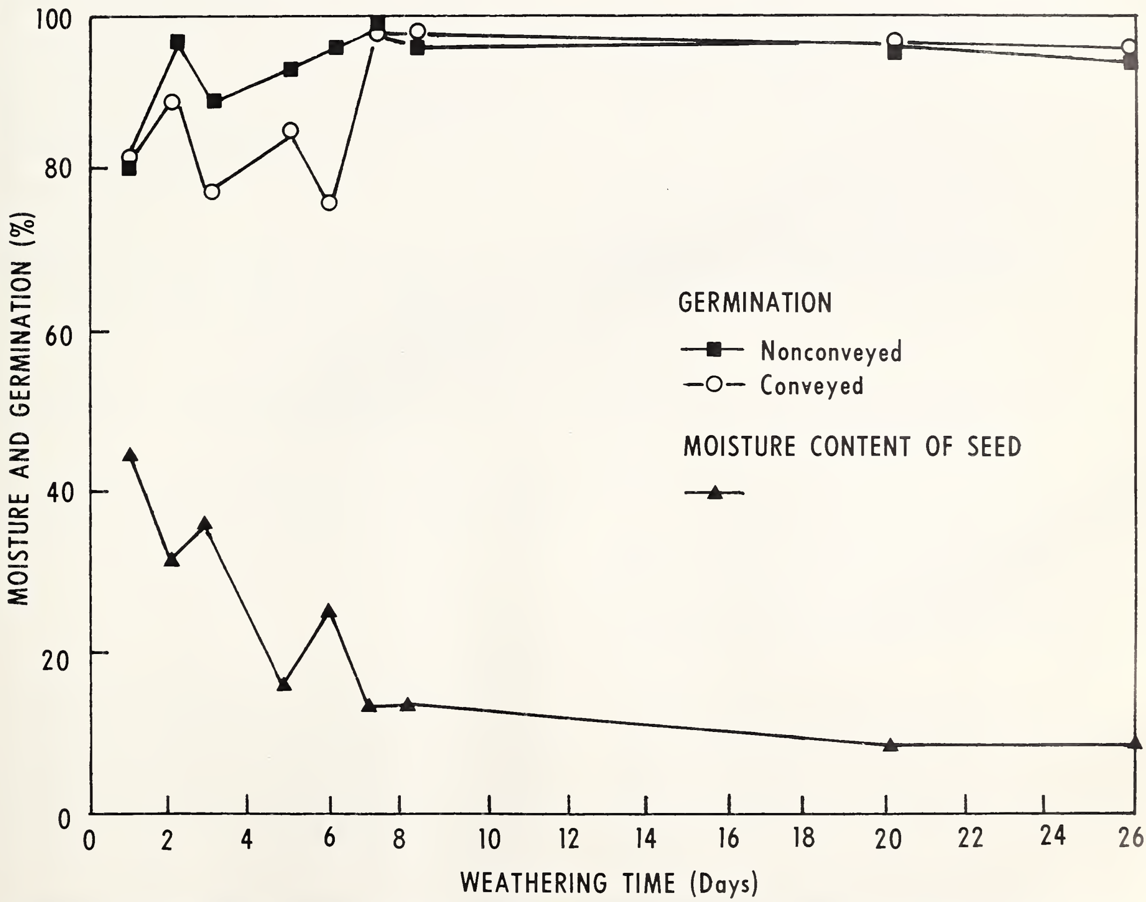


FIGURE 26.—Germination of conveyed and nonconveyed gin-run cottonseed and seed moisture content for different weathering periods.

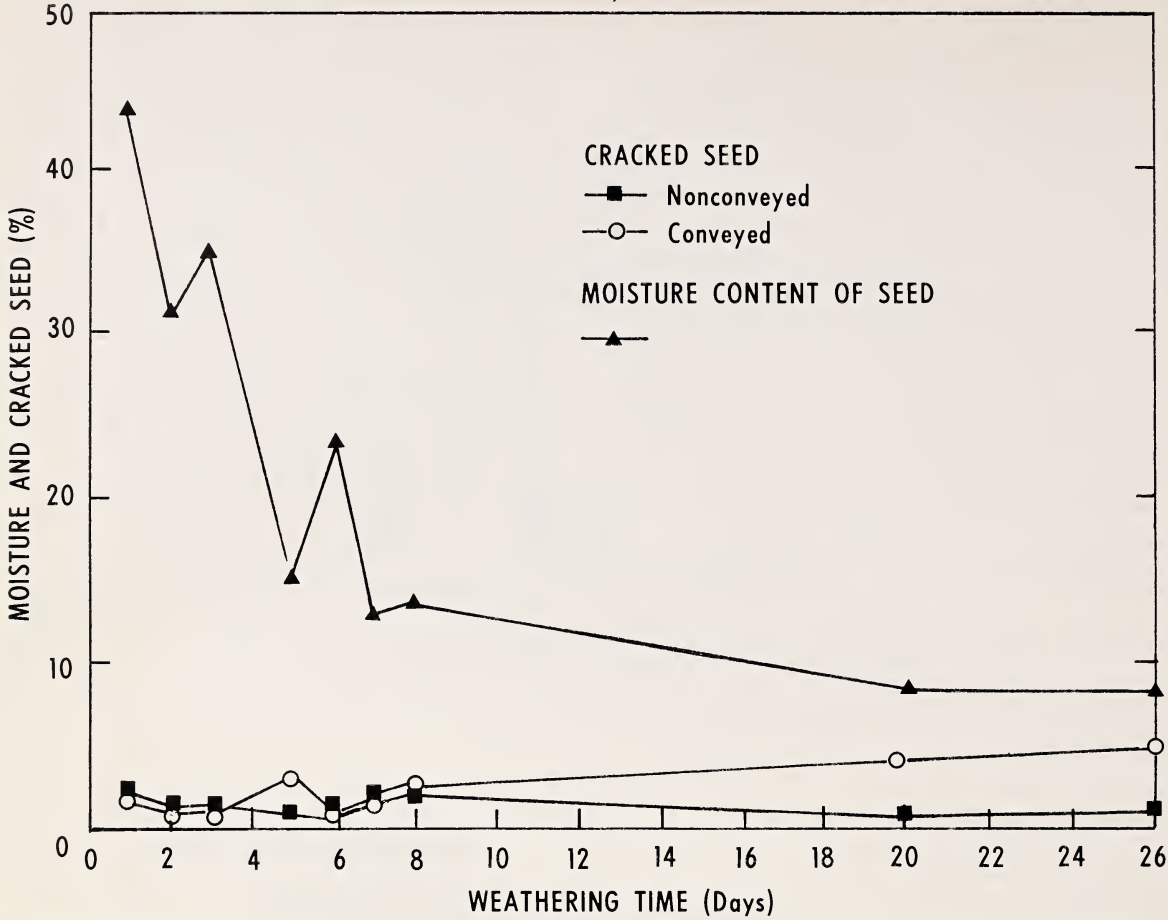


FIGURE 27.—Percentage of seed having cracked seedcoats for conveyed and nonconveyed samples versus weathering times. Plotted along with moisture content versus weathering time curve.

suffer as much deterioration as that which received rain during the opening stage.

In the slow compression test in which seeds were compressed until initial rupture, both the force and energy needed to cause initial rupture were markedly influenced by seed moisture content.

As seed moisture content increased from approximately 10 to 44 percent, the force to cause initial rupture decreased linearly from about 22 lb. at 10 percent moisture content to approximately 12 lb. at 44 percent. The average energy required to cause initial rupture had a maximum value of 0.57 in.-lb. at approximately 14 percent seed moisture content. The energy required to cause rupture decreased to approximately 0.38 in.-lb. at a seed moisture content of about 8.3 percent. At high seed moisture contents, 35 and 44 percent, the rupture energies were 0.35 and 0.32 in.-lb., respectively.

Studies of Rate of Boll Opening

Procedure

These studies were performed to determine for a given time of harvest the number of bolls that would contain seeds that were more susceptible to damage because they had been open less than 4 to 6 days. The tests were conducted in 1966, 1967, and 1968.

Twenty 10-foot observation rows were selected at random from a field containing approximately 2 acres of cotton. Beginning at a time when less than 5 percent of the bolls were

open, counts were made on the same 10-foot rows on each counting date.

Some of the erratic responses in opening rate that were observed from the 1966 counts seemed to be closely correlated between opening rate of the bolls and open-pan evaporation.

The open-pan evaporation measurements were made at Clemson, S.C., 7 miles from where the cotton was grown. In 1967, these measurements were made in the field where the boll opening was measured utilizing porous, porcelain atmometer spheres. The atmometers were placed within the plant canopy approximately 18 inches above the ground.

In the 1968 tests, the atmometers were placed out in the open, above sod, since this was a more practical, repeatable method for obtaining this type of data. They were located within 100 yards of the cotton test areas. Also in 1968 the number of 10-foot sections counted for this test was reduced from 20 to 6. Some difficulty was experienced during 1968 in keeping the atmometer reservoirs filled. For this reason, data were not obtained for the complete period of boll opening.

Results

The rate of opening curve for 1966 is shown in figure 28. The evaporation measurements recorded at Clemson are thought to be reasonably close to those that would have been obtained with open pans at the field. A comparison of the two curves for boll opening and pan evaporation is shown in figure 29. The similarity in the shapes of the curves indicates that evaporation could possibly be used as a good indicator for boll-opening potential.

The correlation between rate of boll opening and atmometer evaporation was also very close in 1967 (fig. 30). A freeze, however, terminated the experiment when about 25 percent of the bolls were open.

Using the percentage open bolls curve in figure 28, the number of bolls that had opened within 4 days of the harvest date can be estimated. For example, assume that a defoliant had been applied when the cotton was 65 percent open, about September 30, 1966, in this particular field. Now, if we had waited 7 days for leaf drop, harvesting would have been on October 7, 1966, when approximately 89 percent of the cotton was open. Dropping back 4 days from October 7, we find that approximately 74 percent of the cotton was open. Thus at harvest, 15 percent (89–74) of the bolls had been open 4 days or less. Estimating on the conservative side, we could assume that half this, or 7 percent, would be harvested by a picker.

Consider now the effect of this 7 percent of freshly open bolls on the germination of a 1,000-seed lot harvested from this field. We have then 70 seeds for which the germination would be reduced by 20 percent, thus, 14 of the 70 would not germinate. For the remaining 930 seeds, assume that 1 percent would not germinate, or approximately 9 seeds. Thus, out of the 1,000-seed lot, 23 seeds (9 + 14), or 2.3 percent, will not germinate. From this rather conservative analysis, a few freshly opened bolls could contribute markedly to reduction in germination of an entire seed lot.

The rate of opening and atmometer evaporation curves for 1968 are shown in figure 31. Again during this year there was a fairly close relationship between the slopes of the two curves. As shown in figure 32, however, the relationship between percentage open bolls and cumulative atmometer evaporation was not linear as was observed for the early opening period in 1967. The correlation, however, was still very high for the quadratic response curve.

A much more detailed study would be required to establish accurately the relationship between boll opening and evaporation. The fruiting rate, planting date, and, perhaps, other related agronomic factors would need to be considered. The data taken in conjunction with this study indicate that a standard measurement of evaporation could be used as an indicator for rate of boll opening.

Laboratory Studies on Doffer Damage

Five high-speed movies were made of the doffing operation on a laboratory-mounted spindle picker. The objectives of these tests were as follows:

1. To determine the doffing action by relative speeds of impact between seed cotton and doffer lugs, and the presence of pinching or tearing action on the seed.

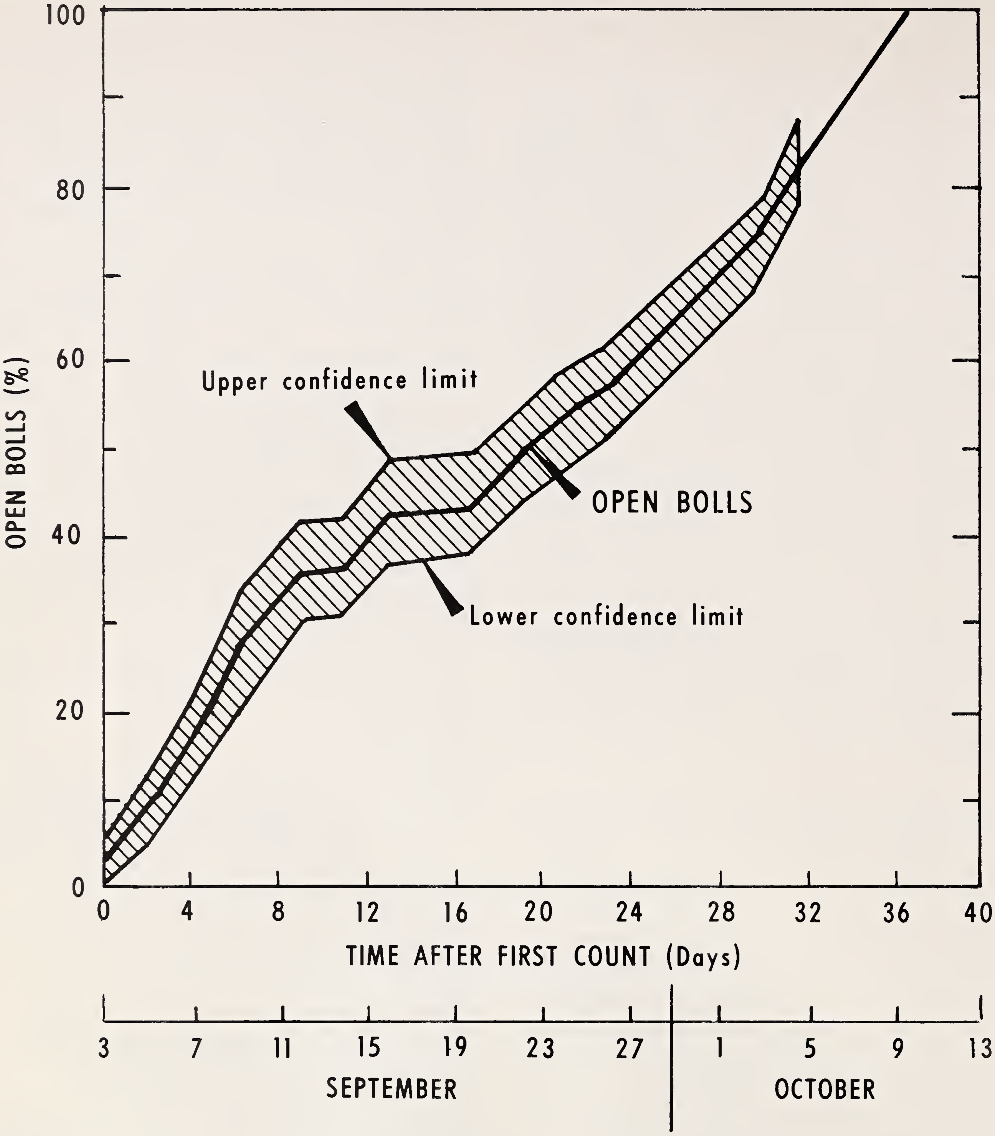


FIGURE 28.—Rate of opening curve with 99 percent confidence limits for the individual observations (Simpson Experiment Station, 1966).

2. To determine, within broad limits, the effects of seed cotton moisture content on doffing action.

3. To determine the effects of three different doffer-spindle clearances on doffing action ($\frac{1}{64}$ in., $\frac{1}{32}$ in., and $\frac{1}{16}$ in.).

Because of the high cost of film and the low quality of the test cotton, not all of the planned tests were carried out.

Eight-foot sections of cotton rows were clamped between two 1- by 4-in. boards. The stalks were then cut beneath the boards and carried into the laboratory. The sections were placed on a small dolly that could be pulled through the laboratory picker at the recommended field speed. Before each test, a 5-boll sample of seed cotton was picked from the row for moisture content determination. The spin-

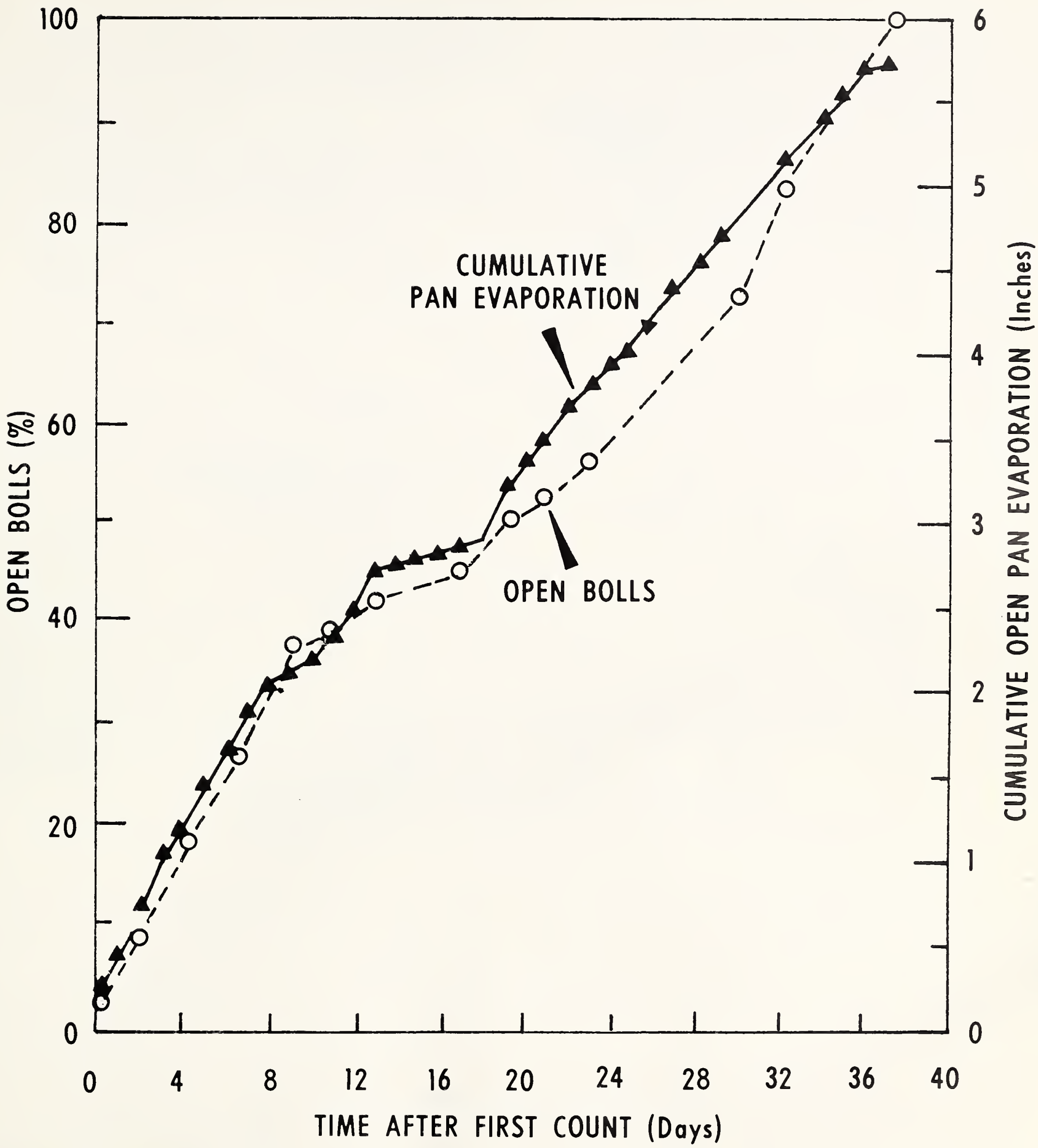


FIGURE 29.—Cumulative open-pan evaporation and percentage open bolls, 1966, showing similarity between rates.

dle-doffer clearance was measured with a feeler gage. The camera operating voltage was set at 70 volts, resulting in a maximum film speed of approximately 3,200 pictures per second. Some of the pertinent data for each movie are given in table 19.

Analyses of the five high-speed movies indicated two causes of seed damage at the doffing position:

1. Pinching of the cottonseed between the spindle and the doffer.

2. Pulling off fragments of seedcoats while adjacent spindles are competing for the same boll of cotton.

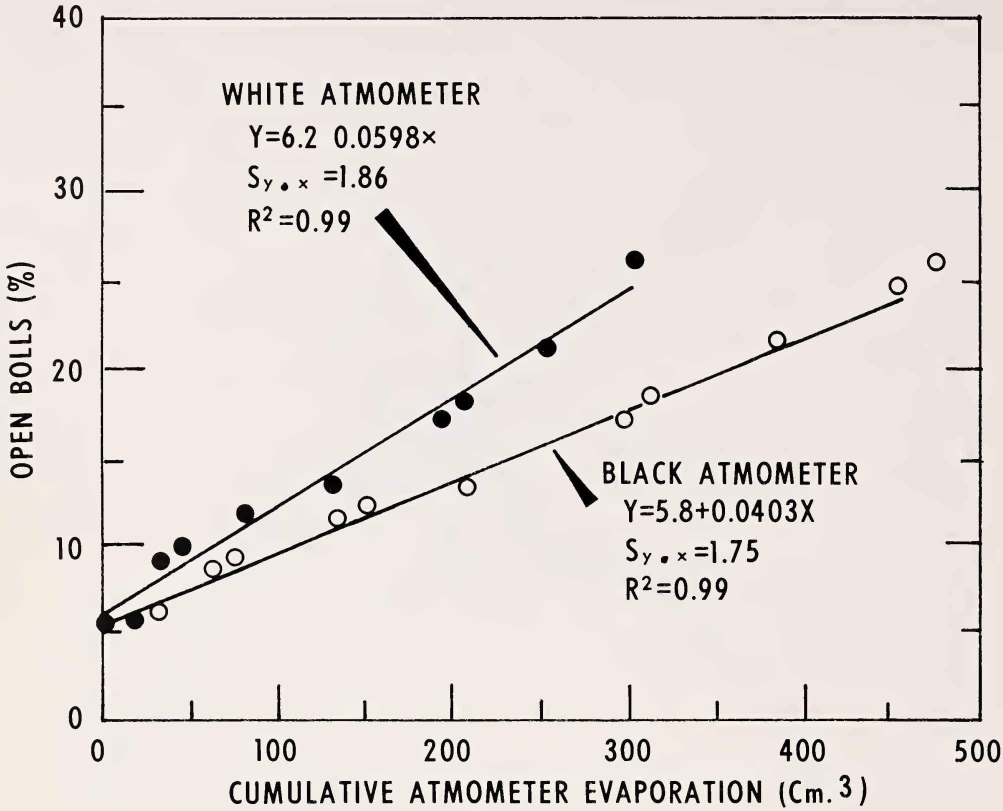


FIGURE 30.—Relationship between rate of boll opening and cumulative atmometer evaporation, 1967.

The same doffer doffed all 29 bolls observed in the movies. The adjacent row of spindles in the field of view did contain some cotton but the doffer clearance was slightly in excess of the desired value. Therefore, no data from this row of spindles are reported.

The first cause of damage, pinching, was indicated by an upward deflection of the lugs on the doffer, which occurred nine times during the doffing of 29 bolls. This deflection could have been caused either by seed under the doffer or tightly wrapped bunches of cotton.

Spindle robbing, or competition, was observed on 19 of the 29 bolls. This condition occurred each time the adjacent spindle contained no cotton.

A summary of the data obtained from the analyses of the high-speed movie is given in table 20. Apparently, doffer adjustment had an effect on doffing of the high-moisture cotton (movies 2, 3, 4,), where the number of doffer lugs dealing significant blows to the cotton on the spindles, before complete doffing, are greater. The 1/32-inch clearance actually resulted in quicker doffing than the 1/64-inch clearance with the high-moisture cotton. However, the spindles were not cleaned of small tufts of lint as well at this setting. The 1/16-inch clearance was obviously an unsatisfactory setting in both number of blows and in completeness of doffing.

Utilizing measurements taken from the high-speed photographs and operating data on spindle speeds, we made an analysis to determine the theoretical impact velocity with which the doffer would strike a cottonseed at a 1/2-inch radius from the center of the spindle. Three velocity components were considered:

1. The component due to spindle rotation of 2,020 r.p.m., counterclockwise, looking into the pointed end of the spindle. Using the formula $V_s = 2\pi r_s n_s$ for the tangential velocity of the spindle where:

r_s = radius from center of spindle to point where cottonseed would be struck, assumed to be one-half inch.

n_s = speed of spindle 2,020 r.p.m., the value V_s = 528 f.p.m. was obtained.

2. The component due to the rotation of the drum which rotated the spindle into the doffers. From measurements taken from the high-speed movies, a value of 126 f.p.m. was obtained for this component.

3. The component due to rotation of the doffer at 888 r.p.m. Again utilizing the formula:

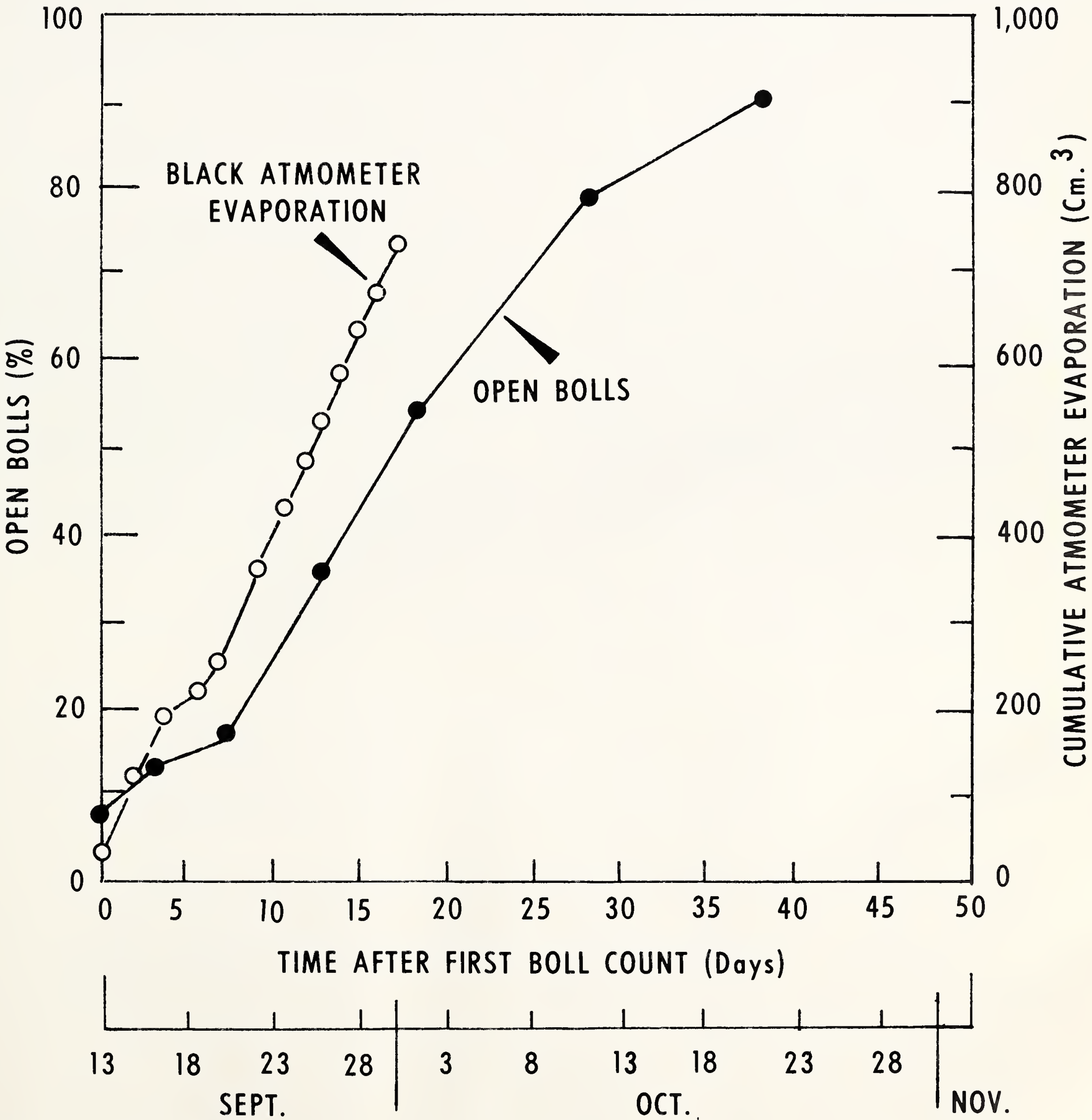


FIGURE 31.—Percentage open bolls and cumulative atmometer evaporation versus time, 1968, Coker 413 cotton. Each point on percentage open bolls curve represents the average of six replications.

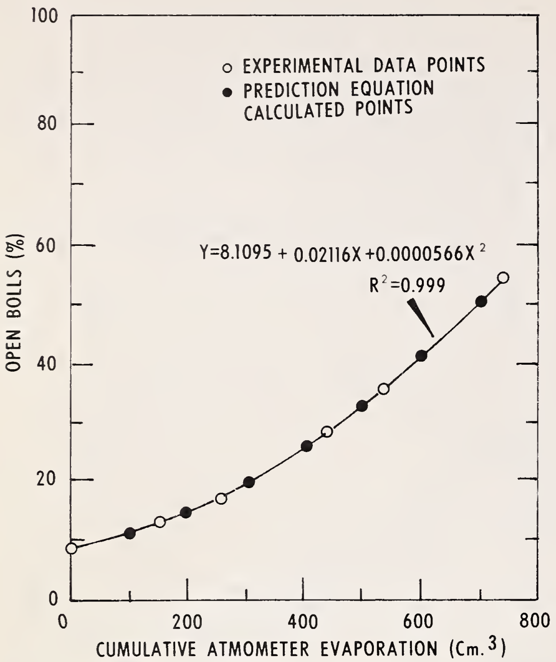


FIGURE 32.—Percentage open bolls versus cumulative evaporation from black atmometer sphere, 1968 (atmometer data not accurate after 54 percent bolls open because of open reservoir).

$$V_d = 2\pi r_d n_d, \text{ where}$$
$$r_d = 3.69 \text{ in.}$$
$$n_d = 888 \text{ r.p.m.}$$

The value $V_d = 1{,}715$ f.p.m. was obtained for this velocity component.

The possible condition that would give the maximum resultant velocity would occur when the spindle component of velocity was directed vertically upward. The velocities would then be directed essentially at right angles to each other and the resultant velocity would be:

$$V_R = \sqrt{V^2_{\text{spindle}} + V^2_{\text{drum}} + V^2_{\text{doffer}}}$$

$$V_R = \sqrt{(528)^2 + (126)^2 + (1{,}715)^2} \text{ f.p.m.}$$

$$V_R = 1{,}799 \text{ f.p.m.}$$

From this calculation and the results of previous impact tests, doffer damage was probably not due to impact with the particular type picker utilized for this test. A check on the specifications of a picker made by another manufacturer revealed that damage by impact at the doffer was again highly improbable.

This study of doffing was limited because the principle of stationary strippers for doffing was not investigated.

TABLE 19.—*Selected operating conditions for 1967-68 high-speed movie studies*

Movie number	Date of run	Approx. seed cotton moisture content (% wet basis)	Doffer-spindle clearance (in.)	Qualitative condition of cotton
1	10/26/67	5	1/64	Slightly immature, dried in laboratory.
2	1/ 2/68	21	1/64	Highly weathered, brittle stalks, wet.
3	1/ 2/68	21	1/32	Highly weathered, brittle stalks, wet.
4	1/ 2/68	22	1/16	Highly weathered, brittle stalks, wet.
5	2/19/68	5	1/64	Highly weathered, brittle, dry.

TABLE 20.—*Data obtained from high-speed movies of doffing with spindler picker*

Movie number	Moisture content of cotton	Doffer-spindle clearance	Bolls observed	Av. lug blows required to doff	Times lugs deflected upward	Times of spindle robbing
	Pct.	*In.*	*No.*	*No.*	*No.*	*No.*
1	5	1/64	7	5.1	4	5
2	21	1/64	5	5.6	1	3
3	21	1/32	10	3.3	3	7
4	22	1/16	5	9.0	0	3
5	5	1/64	2	5.5	1	1

Laboratory Studies on Fan Damage

Procedure

Many cotton harvesters on farms today were built to convey seed cotton through a fan. Although the trend is now away from this practice, minimizing seed damage in present machines is needed. This fan study was designed to determine the effect of (1) fan wheel design, (2) fan scroll design, (3) fan speed, and (4) entry position of cotton into the fan on damage to cottonseed. An apparatus was designed and constructed which permitted the variation of each of these parameters. A study was performed to evaluate the effect of these parameters in the laboratory.

Three fan wheel designs used in the study were: (1) A backward-curved blade with a 6-inch radius of curvature; (2) a backward-curved blade with a 12-inch radius of curvature; and (3) a straight-blade design. Each fan wheel contained six blades, 4 inches wide, spaced at equal angles around a central shaft. These blades were welded on one side to a 20-inch-diameter steel plate, ⅛ inch thick.

The fan design technique described by Madison (*13, p. 221*) was utilized to develop three scroll designs that would yield different clearances between the outer scroll profile and the periphery of the fan wheel. The designs for the three scroll profiles utilized in these tests are shown in figure 33.

Entry position was measured in polar coordinates with the entry radius being measured from the center of the shaft and the entry angle being measured clockwise from the 12 o'clock position. This position had a definite effect on the path taken by the seed cotton; some positions resulted in cotton being carried around the scroll a second time. To feed the cotton into the fan, a turntable feeder and a 3-inch-diameter suction pipe were arranged to permit entry from various positions. Suction from the fans was great enough to pick the cotton up from the turntable and pull it into the fan wheel through the 3-inch pipe.

The flow path of cotton for the three types of blades was studied by high-speed photography as was the influence of two entry positions. An equation was derived for characterizing the radial displacement of locks of cotton along the fan blade as a function of entry position and angular displacement of the fan wheel. The reliability of this equation was evaluated from the high-speed movies.

Damage to cottonseed was analyzed by con-

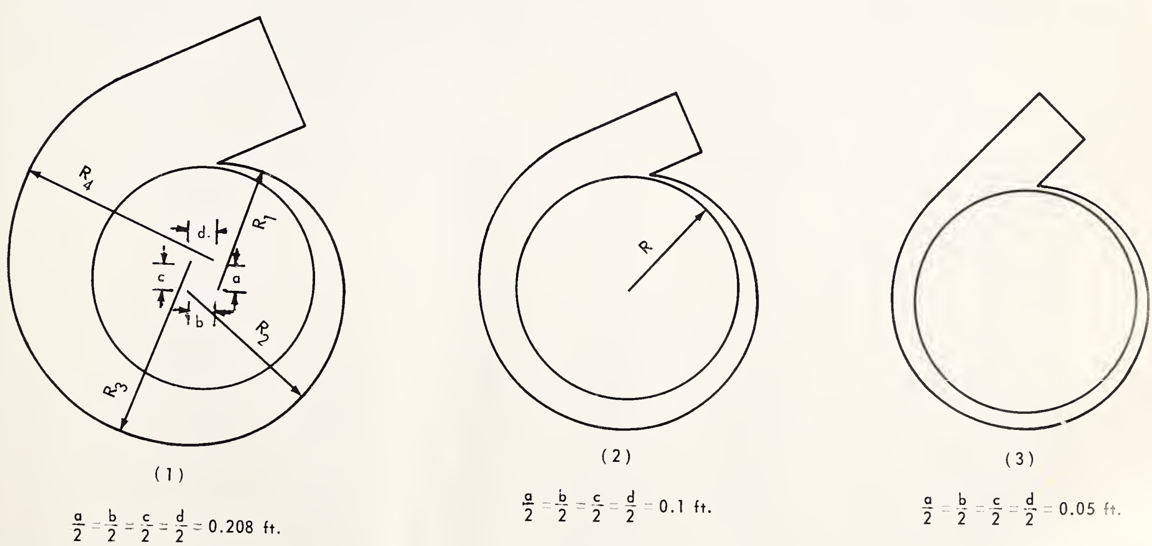


FIGURE 33.—Illustration of three scroll designs utilized in the fan damage study, showing method of development of scroll profile (1). R = radius of fan wheel, same for all tests. Scale ½″ = 1.0″.

veying conditioned seed cotton through the fans for a limited number of speeds and entry positions. The seed cotton samples were then acid delinted and visually inspected for cracked seedcoats. The flow rate of cotton through the fan was approximately 300 lb./hr. which was much lower than would occur in a picker fan.

Handpicked seed cotton (Coker 413 variety) was allowed to reach an equilibrium moisture content of approximately 9.5 percent in a humidity-controlled room for about 2 weeks. Samples were then taken for four replications for each treatment. The samples, weighing 30 grams each, were removed immediately from the conditioning room before being tested and conveyed through the fan test apparatus.

After passing through the fan, the samples were caught in a catch box that had rubber-covered grates, a burlap baffle, and a sponge rubber bottom. This arrangement allowed the air to escape with minimum injury to the seeds after they left the fan.

Results

Results of the fan damage tests are given in table 21. These data show that, of the variables studied, fan speed and blade design (radius of curvature) exert the primary influence on seed damage. A fan speed of 2,330 r.p.m. resulted in from 2 to 4 times as much damage as a fan speed of 1,800 r.p.m.

Seed damage was also greater for the 12-inch backward curve and the straight-blade fan wheels than for the 6-inch backward curve. High-speed movies of these fans indicated that the 12-inch and straight-blade designs caused more friction between the seed cotton and the fan blades, hence the cotton stayed in contact with the blades longer and was thrown harder when it left the blades. A check on the air velocity delivered by the straight blade fan and the 6-inch radius of curvature revealed that the straight blade delivered approximately twice the amount of air at the same speed.

TABLE 21.—*Percentage of cottonseed having viable cracks for different fan parameters*

Shape of fan blade	Scroll development center displacement	Fan speed	Radius of entry point relative to shaft center	Angle of entry point-clockwise from upward vertical	Cottonseed with visible cracks [1]
	Ft.	*R.p.m.*	*In.*	*Degree*	*Pct.*
Straight	0.1	1,800	3	90	53.84a
6-in. radius	.1	2,330	2	90	46.46 b
6-in. radius	.1	2,330	3	90	45.78 b
12-in. radius	.1	1,800	3	90	42.20 b
6-in. radius	.1	2,330	5	90	41.84 b
6-in. radius	.1	1,800	3	90	20.35 c
6-in. radius	.1	1,800	2	300	17.42 cd
6-in. radius	.1	1,800	2	30	16.45 cd
6-in. radius	.05	1,800	3	90	15.66 cd
6-in. radius	.1	1,800	5	90	13.80 cd
6-in. radius	.05	1,800	2	90	13.65 cd
6-in. radius	.1	1,800	2	180	13.64 cd
6-in. radius	.05	1,800	5	90	13.62 cd
6-in. radius	.1	1,800	2	90	13.05 cd
6-in. radius	.208	1,800	2	90	12.90 cd
6-in. radius	.208	1,800	3	90	11.44 d
6-in. radius	.208	1,800	5	90	9.94 d

[1] Percentages followed by the same letter or letters are not significantly different at the 0.5 percent level.

When the cotton entered the fan wheel at a radius of 3 inches as compared with the 2-inch entry radius, the trend seemed to be toward higher seed damage. This difference in damage, however, was not statistically significant. The lowest damage values were obtained with the scroll design that had the maximum clearance between the scroll and the fan wheel. This difference in damage was also not statistically significant.

Summary and Conclusions

Studies were conducted from 1965 to 1968 by the Agricultural Engineering Department, Clemson University, Clemson, S.C., to determine (1) the degree of damage to cottonseed quality at specific critical points in spindle-type cotton pickers, and (2) the influence of maturity and weathering of seed cotton on mechanical damage to cottonseed.

Both field and laboratory experiments were conducted to determine the damage occurring during picking and doffing, in the elbows of the pneumatic conveying system, during conveyance through fans, and upon striking the cleaning grates of the picker basket.

The influence of maturity and weathering was studied utilizing a boll-tagging procedure so that the length of time that bolls had been exposed to weather would be known.

A spindle-type mechanical harvester injured cottonseed both by reducing germination and by creating visible seedcoat cracking. A small amount of damage occurred in the picking and doffing operations, but the greatest damage occurred in the pneumatic conveying system.

Impact velocities on seed cotton in a 90° Plexiglas elbow below 6,000 f.p.m. caused very little cracking for all stages of weathering; however, cotton weathered only one day was reduced drastically in germination by impact velocities above 3,300 f.p.m. Two-day weathered cotton sustained less damage. For all other stages of weathering, the germination reductions due to impact were small at all velocities. Cottonseed at moisture contents of approximately 12 to 13 percent were neither reduced in germination nor cracked appreciably by impact in the 90° elbow, while seed with moisture contents below and above this range sustained damage.

The rate of boll opening is influenced by weather conditions after the bolls have cracked open. Seed that received rainfall during the opening period opened at a slower rate and was more susceptible to reduction in germination caused by impact than seed which opened under rapid drying conditions.

There was a good correlation between evaporation rate and rate of boll opening. A few high-moisture bolls can contribute markedly to reduction in germination of an entire seed lot.

Among the fan variables studied, blade design and fan speed had the greatest influence on amount of cottonseed damaged.

Part III. Preharvest Environmental Factors and Seed Cotton Storage Variables Affecting Cottonseed Quality

Introduction

This phase of the research was conducted by the Agricultural Engineering Department of Texas A&M University from 1965 through 1968. Experiments were conducted on the Brazos River Field Laboratory near College Station, Tex., and in the laboratories of the Agricultural Engineering Department. The primary purposes of the study were to determine the effects of certain preharvest environmental conditions on seed quality and the effects of storage conditions of seed cotton on seed quality. Quality evaluation was made by standard tests for germination, free fatty acid content of oil, aflatoxin development, and mechanical damage.

Effects of Field Exposure on Seed Quality

The objectives of the study were to determine the effects of exposure time in the field on seed quality as measured by standard germination tests and free fatty acid content of oil in the seed.

Procedure

In the initial phase of the preharvest environment study, replicated, randomized plots of Deltapine TPSA (Texas Planting Seed Association) cotton were studied to determine the effects of field exposure on the quality of cottonseed. The cotton was grown with supplemental irrigation in the Brazos River Bottom area near College Station, Tex. Different periods of field exposure were obtained by using two twice-over harvesting procedures and one once-over harvest. All the cotton was defoliated when 70 percent of the bolls were open.

Seed cotton samples from each treatment were dried with forced natural air to a moisture content of approximately 8 percent before ginning. These seeds were then analyzed for germination and free fatty acid content. Quality measurements also were made of seed from cotton handpicked from the bottom half and top half of plants when all the bolls were open.

Results and Discussion

Data presented in table 22 show the effect of time and method of harvest on the germination and free fatty acid content of oil in seed.

Results of 3 years of research show that factors other than the length of exposure time in the field determine the extent of deterioration in seed quality. For example, the quality of seed obtained from cotton exposed in the field for twice-over harvest methods was not correlated with the length of exposure time in the field and varied from year to year. However, when cotton was exposed in the field for a long enough period for a once-over harvest, the seeds were consistently of low quality. As a result, no one exposure period could be established to insure obtaining high-quality seed with any of the harvesting procedures used.

When a once-over harvest was used, germination was always significantly reduced and free fatty acid content of seed increased from the bottom half of the plant when compared with the same quality measurements for seed from the top half of the plant (fig. 34). This was attributed to the longer field exposure period and more adverse microclimate for seed on the bottom than on the top of the plant. In some plants "boll rot" near the bottom of the

TABLE 22.—*Effect of time and methods of harvest on the germination of cottonseed, 1965-67*[1]

Item	1965	1966	1967
Twice-over harvest			
No. 1:			
First harvest:[2]			
Date	9/15	9/15	8/17
Hand harvested:			
Germination pct	87.9	55.9	84.0
Free fatty acid content pct	.7	3.3	.4
Machine harvested:			
Germination pct	78.0	54.5	75.5
Free fatty acid content pct	.7	2.9	.4
Second harvest:[3]			
Date	10/26	10/14	9/26
Hand harvested:			
Germination pct	80.0	62.5	44.4
Free fatty acid content pct	1.7	.8	1.3
Machine harvested:			
Germination pct	75.0	71.1	38.1
Free fatty acid content pct	2.1	.8	1.8
No. 2:			
First harvest:[4]			
Date	10/11	9/29	8/30
Hand harvested:			
Germination pct	72.9	79.3	76.0
Free fatty acid content pct	2.4	1.4	.4
Machine harvested:			
Germination pct	71.9	75.6	79.9
Free fatty acid content pct	2.4	1.5	.3
Second harvest:[3]			
Date	10/26	10/4	9/26
Hand harvested:			
Germination pct	89.5	50.9	51.4
Free fatty acid content pct	1.1	2.3	.9
Once-over harvest			
Date	10/26	10/14	9/26
Hand harvested:			
Germination pct	74.0	58.3	24.3
Free fatty acid content pct	4.5	2.2	1.7
Machine harvested:			
Germination pct	74.5	69.5	31.8
Free fatty acid content pct	3.0	1.5	1.7

[1] First open bolls observed on August 20 in 1965 and 1966 and on July 25 in 1967.

[2] Seed from cotton harvested at the following stages of maturity based on the percentage of open bolls: 50 percent in 1965; 33 percent in 1966; and 63 percent in 1967.

[3] Harvested when the remaining bolls on the plant were open.

[4] Seed from cotton harvested at the following stages of maturity based on the percentage of open bolls: 75 percent in 1965; 67 percent in 1966; and 83 percent in 1967.

plant was excessive, indicating an unfavorable environment for preserving quality.

In considering the factors that contributed to this loss in quality, the microclimate surrounding the plant may be more important than the length of field exposure time in obtaining high-quality seed. The rank growth and dense foilage of plants used for this research produced an unfavorable microenvironment and was not conducive to producing high-quality seed. Plants were 4 to 5 feet high and completely overlapped in the middles, but not lodged.

Another factor that could contribute to deterioration in seed quality is the response time for changes in seed cotton moisture content under different environmental conditions. An example of the changes in seed cotton moisture in relation to ambient air temperature and relative humidity is shown in figure 35. Seed cotton moistures responded rapidly to changes

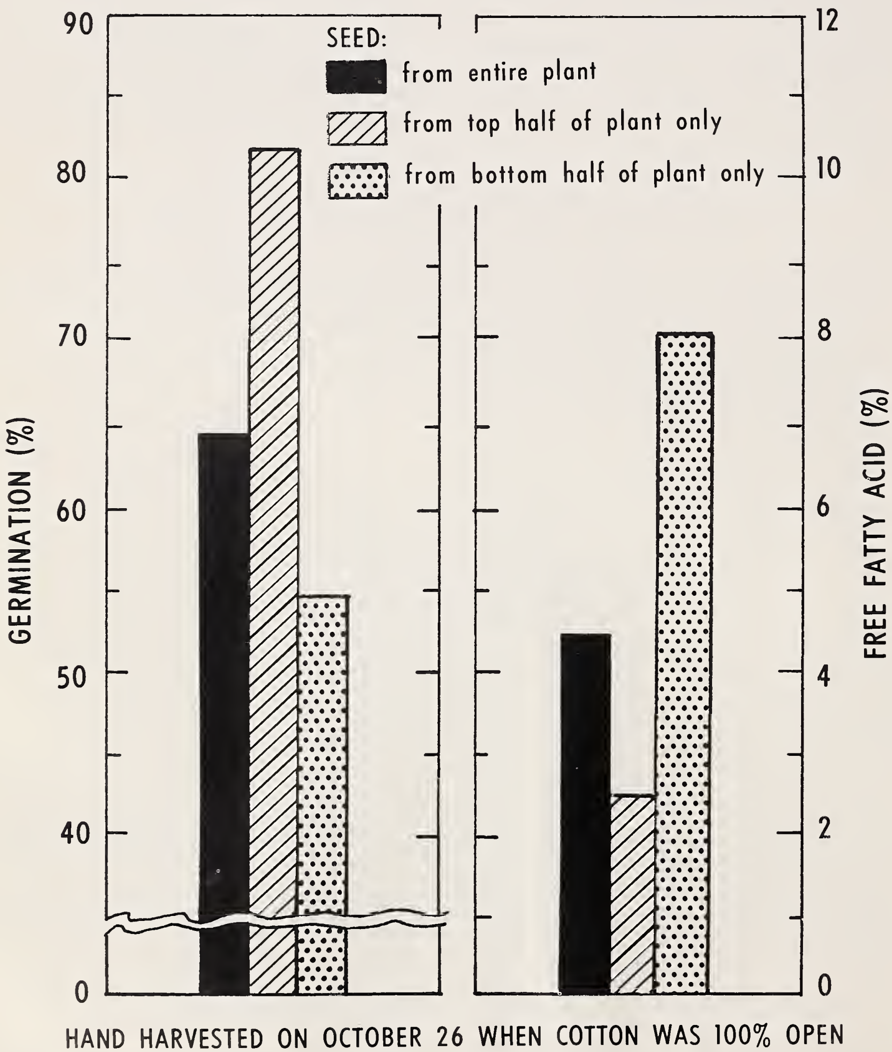


FIGURE 34.—The quality of the cottonseed, based on germination and free fatty acid analyses was consistently lower on the bottom half of the plant than on top half when a once-over harvest was used.

in ambient air conditions. Thus, prolonged periods of high humidity, or even repeated low- and high-humidity conditions during the day and night, could produce unfavorable environments for a sufficient length of time to cause excessive deterioration in seed quality.

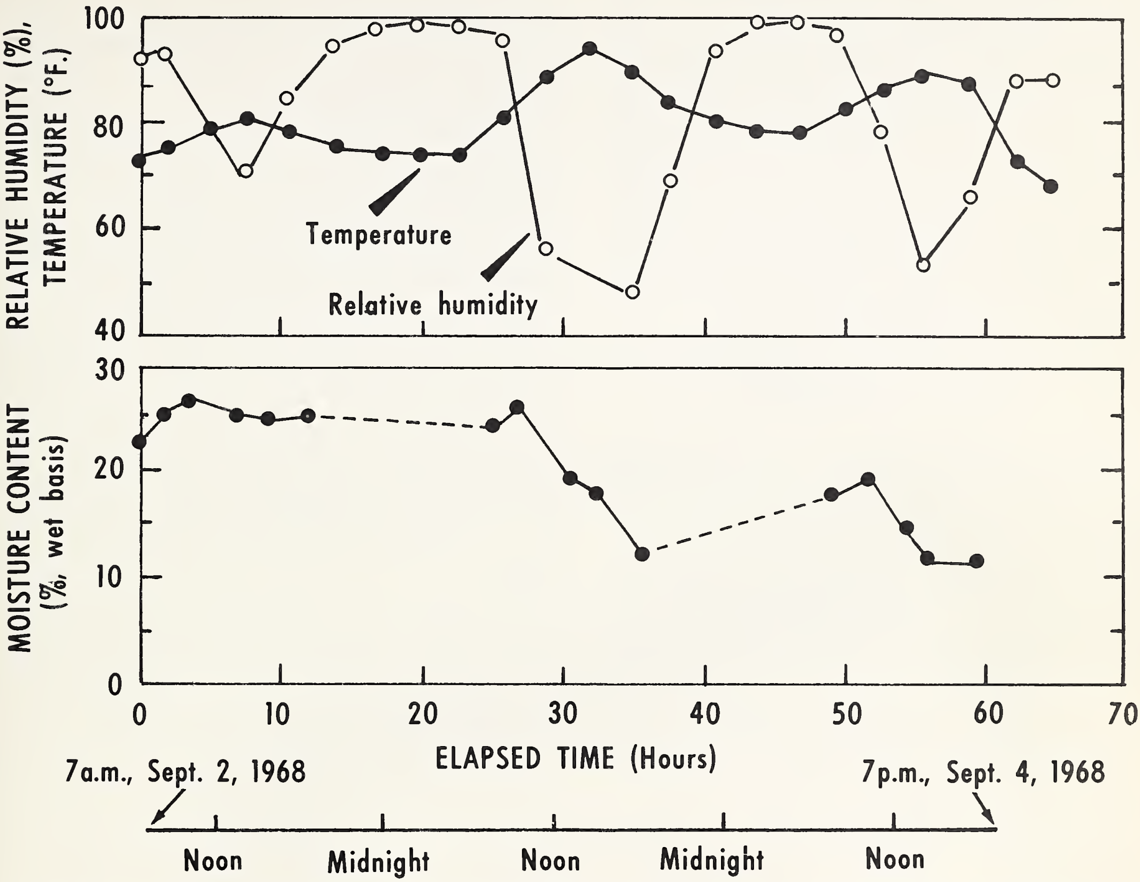


Figure 35.—An example of the changes in seed-moisture content in relation to ambient air temperature and relative humidity.

Relationship of the Microenvironment to Seed Quality

Based on the results of the time-of-harvest studies and the considerations discussed under field exposure studies, research was started in 1967 to determine the relationship of certain microenvironmental factors to seed quality.

Procedure and Instrumentation

Bolls from different sections of plants in four replicated randomized plots of Deltapine TPSA cotton were tagged at the time they were beginning to open. Only the bolls that were just cracked open (width of opening a maximum of one-half inch) were tagged.

Four days were allowed for the bolls to open completely after tagging. The fifth day after tagging was considered the first day of field exposure. Of these tagged bolls, 25 were hand harvested from each plot on the fifth day after tagging and were considered to have no exposure in the field. Thereafter, the same number of bolls were harvested from each plot at weekly intervals for 5 weeks.

After the bolls were harvested, atmospheric air was forced through the samples to remove excess moisture from the lint and the seed. Each sample was ginned in a laboratory roller gin. Standard germination tests were then made of seed for each exposure period.

Records were maintained of dry-bulb, wet-bulb, and black-globe temperatures of the ambient air and of the air surrounding the plants in each plot. Ambient air conditions were taken 30 inches from the ground in an area adjacent to the plots. Temperatures of the air surrounding the plants were taken near the ground level and just below the top of the cotton plants between the rows of cotton plants.

Results and Discussion

Average dry-bulb temperatures and relative humidities of the ambient air in the adjacent alleyway and the air near the bottom and top of plants for bolls tagged on different dates are shown in table 23. No appreciable difference was found in the ambient air and plant microenvironment temperatures. However, the average relative humidity of the air near the bottom of the plants was always higher than the relative humidity of the ambient air and the air near the top of the plants. For example, the average relative humidity near the bottom of the plants for a 28-day exposure period, August 8 to September 5, was 76.3 percent compared with 74.4 near the top of the plants and 72.5 percent for the ambient air.

Germination of the seed after different intervals of field exposure is shown in table 24. A seed quality index was established by relating these data to the number of hours seed cotton was exposed to relative humidities above some predetermined base. The term "R.H.-hour" was adopted for this purpose and is based upon relative humidity difference and time. For any one hour, when the relative humidity is above a predetermined base, there exists as many relative humidity hours (R.H.-hours) as there are percentage points relative humidity above the designated base. This takes into account not only the time of exposure but also the severity of the conditions existing during the exposure period.

The effect of microclimate and ambient R.H.-hours (using an 85 percent base) on the germination of seed from bolls tagged on dif-

TABLE 23.—*Average dry-bulb temperature and relative humidity of ambient air and air near the bottom and top of plants for the field exposure period, August 8 to October 6, 1967*

Days of field exposure	Dates exposed	Dry-bulb temperature			Relative humidity		
		Bottom [1]	Top [1]	Ambient air	Bottom [1]	Top [1]	Ambient air
		° F.	*° F.*	*° F.*	*Pct.*	*Pct.*	*Pct.*
7	Aug. 8–15	81.8	81.5	84.6	63.4	61.3	58.6
14	Aug. 8–22	80.1	79.7	80.9	72.3	71.2	68.3
21	Aug. 8–29	79.3	78.9	79.5	75.8	74.3	72.6
28	Aug. 8-Sept. 5	79.4	78.9	79.1	76.3	74.4	72.5
7	Sept. 2–9	73.6	72.6	72.8	88.1	84.2	83.6
14	Sept. 2–16	75.6	74.8	75.0	83.2	80.8	78.5
21	Sept. 2–23	76.0	75.4	75.5	85.5	82.9	79.1
28	Sept. 2–30	73.7	73.3	73.3	84.0	82.2	77.7
35	Sept. 2-Oct. 6	73.6	73.2	73.2	83.5	82.0	77.9

[1] Average of 4 replications.

ferent dates and hand harvested at weekly intervals is shown in table 25. In these tests, germination decreased significantly after a field exposure period involving 3,384 to 4,352 R.H.-hours, or 289 to 366 accumulated hours above 85 percent relative humidity, based on the air conditions surrounding the plants. Based on ambient air, germination decreased significantly after an exposure period of 2,196 to 2,342 R.H.-hours, or 252 to 324 accumulated hours above 85 percent relative humidity. These results are based on dry-bulb temperatures ranging from 73° to 85° F. In other areas where the temperatures are lower during the harvest period, a longer exposure period probably could be allowed before deterioration in quality occurs.

TABLE 24.—*Germination of cottonseed from bolls harvested at different intervals of field exposure, 1967*

Days of field exposure	Germination (percent) [1]	
	Bottom of plant	Top of plant
	Pct.	*Pct.*
0	89.1	82.0
7	87.0	87.4
14	89.5	91.3
21	82.8	80.5
28	90.6	[1] 74.1*
35		[1] 68.3*

[1] Asterisks indicate a significant decrease in germination at the 5-percent level of probability when compared with zero days of field exposure.

TABLE 25.—*Effect of microclimate and ambient R.H.-hours (85-percent base) and the number of hours above 85 percent relative humidity on the germination of seed from bolls tagged on different dates and hand harvested at weekly intervals, 1967*

Days of field exposure	Dates exposed [1]	Accumulated R.H.-hours [2]		Accumulated hours above 85 percent relative humidity		Germination (percent)
		Microclimate	Ambient	Microclimate	Ambient	
0		0	0	0	0	89.1
7	Aug. 8–15	313	238	28	24	87.0
14	Aug. 8–22	1,343	988	116	108	89.5
21	Aug. 8–29	2,517	1,808	210	196	82.8
28	Aug. 8 – Sept. 5	3,384	2,196	289	252	90.6
0		0	0	0	0	82.0
7	Sept. 2–9	1,131	856	90	96	87.4
14	Sept. 2–16	2,025	1,272	162	158	91.3
21	Sept. 2–23	3,172	1,650	267	250	80.5
28	Sept. 2–30	4,352	2,342	366	324	[3] 74.1*
35	Sept. 2 – Oct. 6	5,408	3,128	460	394	[3] 68.3*

[1] Average dry-bulb temperatures of ambient air for each exposure period are shown in table 23.

[2] Based on dry-bulb and wet-bulb temperature measurements at the following locations: (a) Near the bottom of the plants for tagged bolls exposed from August 8 to September 5; and (b) near the top of the plant for tagged bolls exposed from September 2 to October 6.

[3] Asterisks indicate a significant decrease in germination at the 5-percent level of probability when compared with zero days of field exposure.

Quality of Cottonseed From Seed Cotton Stored for Various Periods of Time Before Ginning

The objective of this research was to determine the effects of storing seed cotton under different conditions of moisture and density for various periods of time before ginning on the quality of the seed.

Procedure and Equipment

Replicated samples of seed cotton at different moisture levels were stored at three densities for various periods of time before ginning to determine the extent of damage to the seed during the storage periods. Cotton used in this research was harvested from a field in which approximately 100 percent of the bolls were open at the time of harvest. Different moisture levels were obtained by machine picking the cotton at different times during the day. Seed cotton at each moisture level and storage density was stored for 0, 3, 5, 10, 20, and 30 days.

Dry-bulb temperatures of the air in the stored seed cotton and the air passing around each storage container were recorded at 3-hour intervals, throughout the storage periods. Part of the seed cotton from each treatment was ginned immediately after the sample was removed from storage and the seeds were analyzed for moisture content and mechanical damage. The rest of the sample was dried with forced natural air until the moisture content was reduced to 10 to 12 percent, wet basis. It was then ginned and the seeds were analyzed for moisture content, germination, free fatty acid content, aflatoxins, and mechanical damage.

Seed cotton for these experiments was picked with a one-row mechanical picker. A scaled-down commercial gin was used to gin the samples.

Plywood containers, 1 cubic-foot capacity, (fig. 36) were used to store the seed cotton. In the 1965 experiments, moisture content of seed cotton stored in these containers was significantly reduced. Tests conducted before the 1966 storage studies showed that this moisture loss could be prevented by lining the containers and sealing the top with four-mil polyethylene film. Therefore, all of the containers were sealed in this way for the 1966 and 1967 experiments.

The storage containers for each treatment were placed in special control chambers constructed of ¾-inch plywood (fig. 37). The inside measurements of each chamber were 30 inches wide, 42 inches long, and 54 inches deep. The walls and top of each chamber were lined with 1-inch fiberglass insulation. Conditioned air was supplied to each chamber through a main duct and lateral distribution system. A sliding gate in the top of the control chamber was used to control the volume of air supplied to each chamber. A fan and coil unit, utilizing a 2-ton water chiller, supplied air continuously at a constant dry-bulb temperature of 70° F. to each control chamber.[7]

The tests were designed to maintain a zero temperature differential between the temperature of the seed cotton and the air surrounding the individual storage containers. This was done to prevent a rapid gain or loss of heat to

[7] Cotton storage research is usually reported in Fahrenheit.

PN-2564

FIGURE 36.—Three containers used for seed cotton storage studies. An empty container (No. 74) is shown on the right. A thermocouple was placed in each container as shown at the center (No. 133). Seed cotton packed into each container was held in place by a plywood cover and ⅛-in. rods, shown on the left (No. 101).

or from each container and thus simulate the effect of increased temperature due to biological activity when seed cotton is stored in trailers. Electric light bulbs, shown in figure 38, were located in each lateral duct leading to the control chamber to provide the heat needed to raise the air temperature around the storage containers to the seed cotton temperature. A variable transformer was used to control the voltage to some of the light bulbs in each lateral duct to aid in controlling the air temperature at the required level. A centrifugal fan capable of supplying air at a rate of 60 c.f.m. at free delivery was installed near the air inlet to each control chamber. This fan provided a means of circulating and mixing the air passing around the storage containers and resulted in maintaining a temperature differential of ±1° F. in the control chamber.

The moisture contents of the seed cotton and cottonseed were determined by the gravimetric method, using a forced-draft oven. Samples of seed cotton weighed from 100 to 120 grams and cottonseed from 50 to 60 grams. These samples were placed into the oven for 36 to 48 hours to determine the moisture content. The air temperature in the oven was maintained at 230° F. throughout the test period. All moisture contents are expressed on a wet basis.

Results and Discussion

Moisture content of seed cotton in the 1965 experiments was significantly reduced when seed cotton was stored in unlined plywood containers. This condition was corrected for the 1966 and 1967 experiments by lining the containers with plastic film.

PN-2565

FIGURE 37.—Overall view of control chambers and instrument panels. Recording potentiometers, shown on the left, were used to maintain hourly records of temperatures in each container. Null-balance potentiometer controller (top) and variable transformers are shown on the right.

The 1965 data are not considered representative of actual conditions and, therefore, the results presented in this report are based only on the data obtained in 1966 and 1967.

Moisture Content

Cotton was picked at different times during the day to obtain the range of moisture contents desired for these tests. Examples of the variation in moisture contents of seed cotton and cottonseed picked at different times during the day in 1966 and 1967 are given in figures 39 and 40. Large differences occurred in moisture contents of seed cotton and cottonseed in 1966 with the magnitude increasing during the day. In 1967, the differences were small and the relationship between the moisture contents of the two products remained about the same throughout the test period. A study of the weather records in 1966 showed that a prolonged period of high humidity and rainfall occurred a few days before the time the moisture determinations were made. In 1967, however, a period of low humidity preceded the time moisture contents were determined.

The extreme variations in moisture in 1966 indicated that the moisture contents of the seed and lint were not in equilibrium; this condition may have been due to the high-humidity conditions before the time the cotton was picked for the moisture tests. Apparently, the weather conditions in 1967 were such that the moisture contents of the seed and lint were in equilibrium. These results indicate that seed cotton moisture content should be used as a basis for determining whether seed cotton can be stored without a loss in seed quality.

Cottonseed was obtained at five levels of moisture for these studies (table 26). Within some storage treatments, moisture contents of the seed and seed cotton varied considerably. Also, for moisture level B the moisture content of the seed was much higher than the seed cotton moisture at the start of the storage period. After 5 days of storage, however, the moisture content

PN 2566

FIGURE 38.—Electric light bulbs were installed in each lateral duct to provide the increase in temperature needed to maintain a zero differential between the temperature of the air circulated in each container and the temperature of the seed cotton.

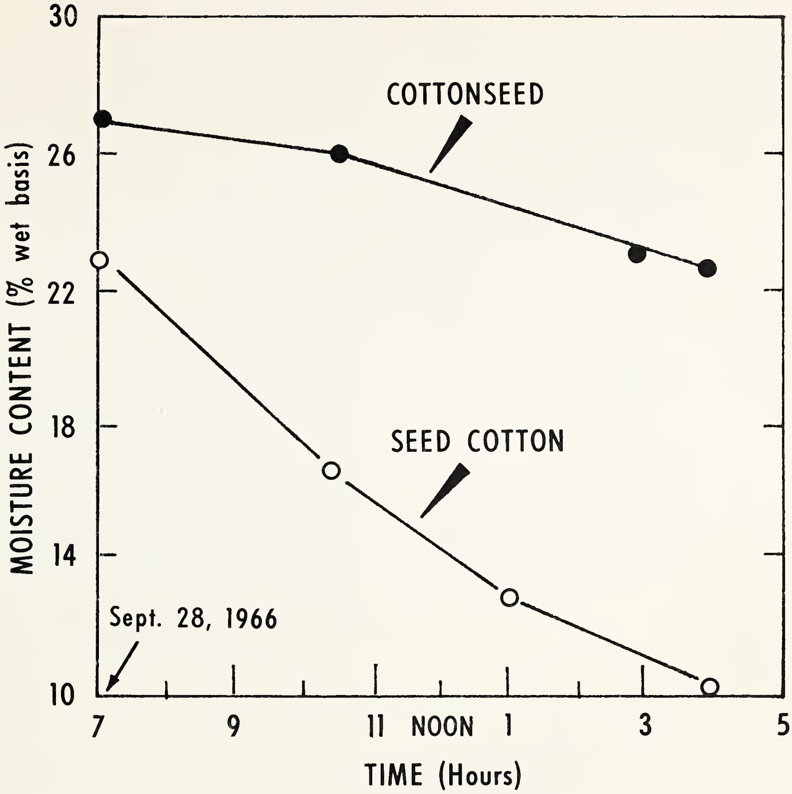


FIGURE 39.—Comparative moisture contents of seed cotton and cottonseed when cotton was harvested at different times during the day in 1966.

of the seed had been reduced to about the same level as the initial moisture content of the seed cotton, indicating that the moisture contents of the seed and lint were in equilibrium.

Seed Cotton Temperatures

Increases in temperature during storage were related to seed cotton moisture content and length of the storage period above certain levels of moisture. There was some indication, also, that the increases in temperature were related to storage density but to a lesser degree than moisture content and length of storage. During a 30-day storage period, temperatures in seed cotton ranged from no appreciable increase when average seed moisture contents ranged from 8.0 to 12.9 percent (moisture levels D and E) to a maximum of 132° F. when average seed moisture contents were 19.3 to 24.5 percent (moisture level A). Representative temperatures in seed cotton stored at different densities during a 30-day storage period are shown in figures 41 to 43, inclusive.

Temperature is a good indication of the extent of biological activity of seed cotton. It can be used as a guide to determine the length of time seed cotton can be held in storage before ginning without a loss in seed quality. An increase in temperature is an indication of unfavorable conditions for maintaining quality; if increases should occur, the cotton should be ginned or the cause of heating eliminated as soon as possible.

Production of Aflatoxins

In 1965, aflatoxins were detected after 10 days' storage in seed with an initial moisture content of 20 to 22 percent. In 1966, aflatoxins were not detected in any of the storage samples even though some of the storage treatments contained seed with moisture contents of 27 to 29 percent. The reason for this difference is be-

lieved to have been due to the seed temperatures and moisture contents existing during the storage periods. In 1965, due to the excessive reduction in seed and seed cotton moisture contents during storage, temperature did not exceed 91° F. during storage. In 1966, however, moisture contents were maintained at the original level throughout the storage period and the temperatures increased rapidly from an initial temperature of 80° to 109° after 3 days' storage and then continued to increase to a maximum of 131° during a 10-day-storage period.

Research conducted by Schroeder and Hein (*18*) showed that the optimal temperature range for aflatoxin production is between 68° and 95° F. and only small amounts of toxins are produced at 50° and 104°.

In 1967, aflatoxins were found in samples at the lowest moisture range of 8.0 to 9.6 percent. The highest concentration, however, was found after 20 days' storage in seed with a moisture content of 14.8 to 15.5 percent when seed cotton temperatures did not exceed 97° F. Aflatoxins were present in several samples dried immediately after the cotton was picked (zero days' storage), indicating that aflatoxins developed in the field before storage.

Germination and Free Fatty Acid Content

Germination and free fatty acid values for seed from seed cotton stored at different moisture contents and storage densities for various lengths of time before ginning are shown in tables 27 and 28. The initial quality of the seed was extremely low. Sometimes the low quality of seed and the wide variations in moisture content within storage treatments make estab-

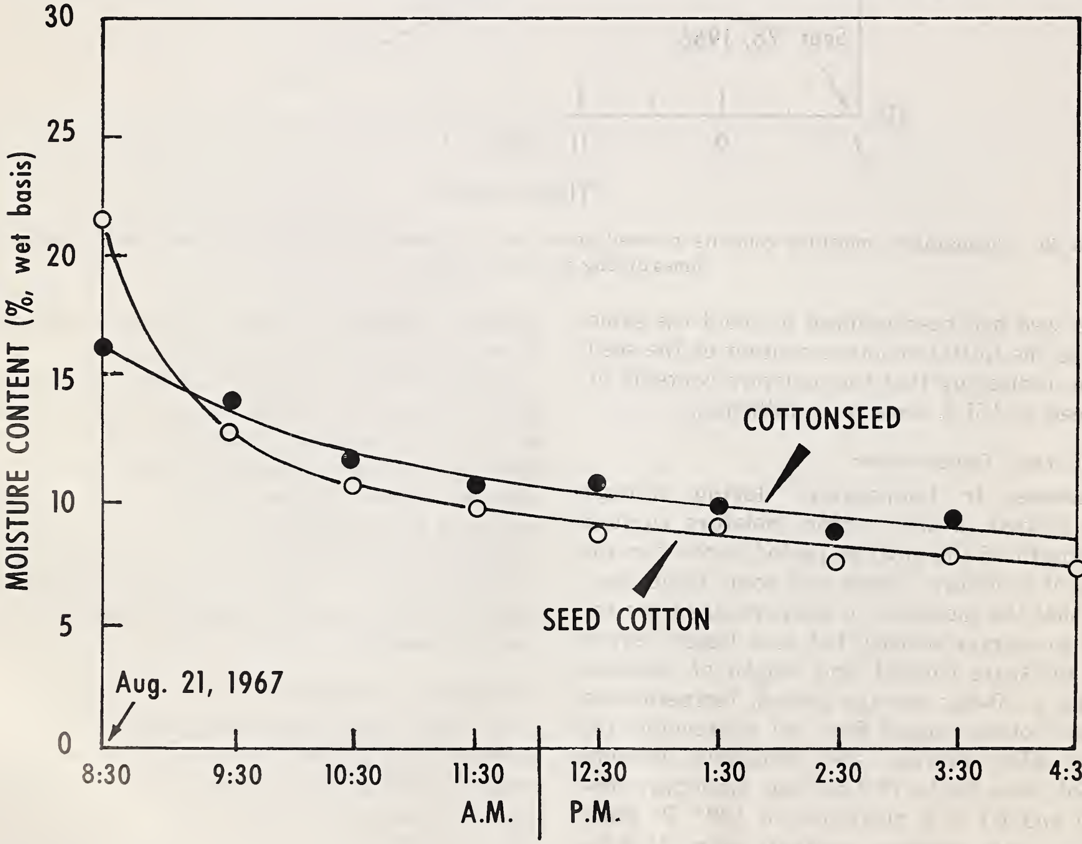


FIGURE 40.—Comparative moisture contents of seed cotton and cottonseed when cotton was harvested at different times during the day in 1967.

TABLE 26.—*Moisture content of cottonseed and seed cotton wet basis at different intervals of storage*[1]

Item	Length of storage period (days)					
	0	3	5	10	20	30
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Moisture level A, storage density—						
7 lb. per cu. ft.:						
Cottonseed	27.9	23.8	24.3	22.3	21.9	19.7
Seed cotton	22.9	28.7	21.3	----------	20.0	19.1
12 lb. per cu. ft.:						
Cottonseed	26.9	24.3	24.5	23.4	22.9	19.3
Seed cotton	23.2	24.8	23.0	----------	19.8	18.2
Moisture level B, storage density—						
7 lb. per cu. ft.:						
Cottonseed	25.2	17.1	19.3	17.3	17.8	----------
Seed cotton	16.7	22.9	17.1	----------	17.4	14.3
12 lb. per cu. ft.:						
Cottonseed	26.8	15.8	19.2	17.1	17.7	15.9
Seed cotton	17.4	23.5	17.6	----------	16.7	15.7
Moisture level C, storage density—						
7 lb. per cu. ft.:						
Cottonseed	12.3	12.4	13.7	12.9	13.0	13.1
Seed cotton	13.9	12.5	12.6	12.4	12.3	13.1
12 lb. per cu. ft.:						
Cottonseed	13.1	13.9	15.1	15.2	15.2	13.7
Seed cotton	13.3	14.4	14.0	14.4	15.4	13.3
Moisture level D, storage density—						
7 lb. per cu. ft.:						
Cottonseed	11.7	11.5	12.9	11.6	11.5	10.9
Seed cotton	11.3	11.8	11.2	11.5	10.8	10.6
12 lb. per cu. ft.:						
Cottonseed	11.3	10.4	12.0	10.5	10.3	11.0
Seed cotton	10.7	10.2	10.3	11.0	9.9	10.9
Moisture level E, storage density—						
7 lb. per cu. ft.:						
Cottonseed	8.5	8.1	9.6	9.0	9.3	9.1
Seed cotton	8.2	7.9	8.1	9.2	8.6	9.1
12 lb. per cu. ft.:						
Cottonseed	8.7	8.0	9.2	8.8	8.8	9.2
Seed cotton	8.9	8.2	8.2	8.4	8.5	9.9
20 lb. per cu. ft.:						
Cottonseed	8.2	9.0	8.9	9.0	9.3	9.1
Seed cotton	8.4	8.5	8.2	8.5	9.0	9.2

[1] Average of 3 replications.

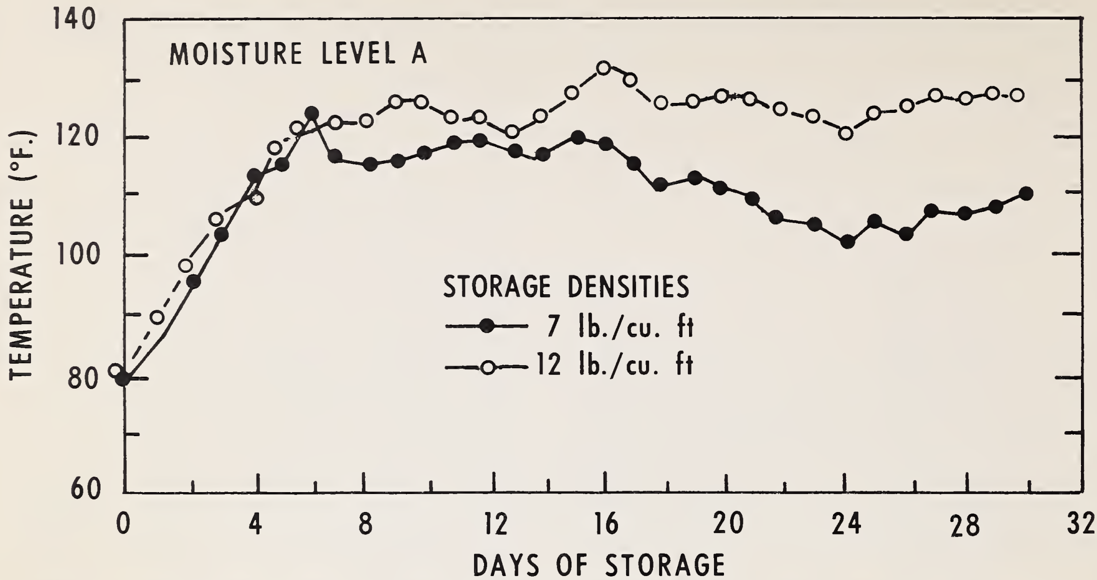


FIGURE 41.—Temperatures in seed cotton for 30 days of storage: Average moisture contents of seed from seed cotton that was stored for time periods of 3, 5, 10, 20, and 30 days ranged from 19.3 to 24.5 percent, wet basis.

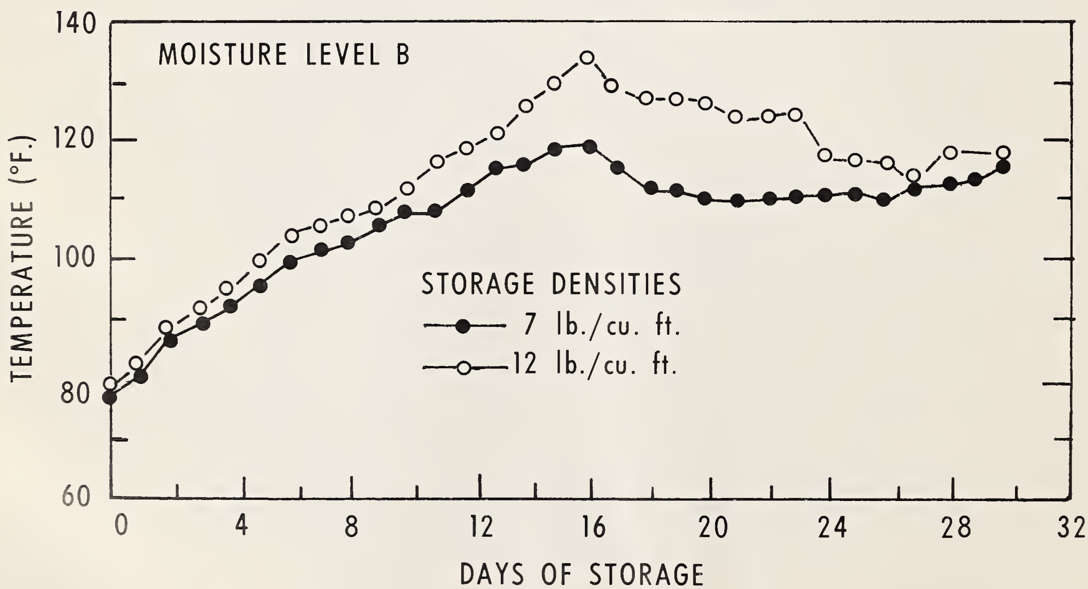


FIGURE 42.—Temperatures in seed cotton for 30 days of storage: Average moisture contents of seed from seed cotton that was stored for time periods of 3, 5, 10, 20, and 30 days ranged from 15.8 to 19.3 percent, wet basis.

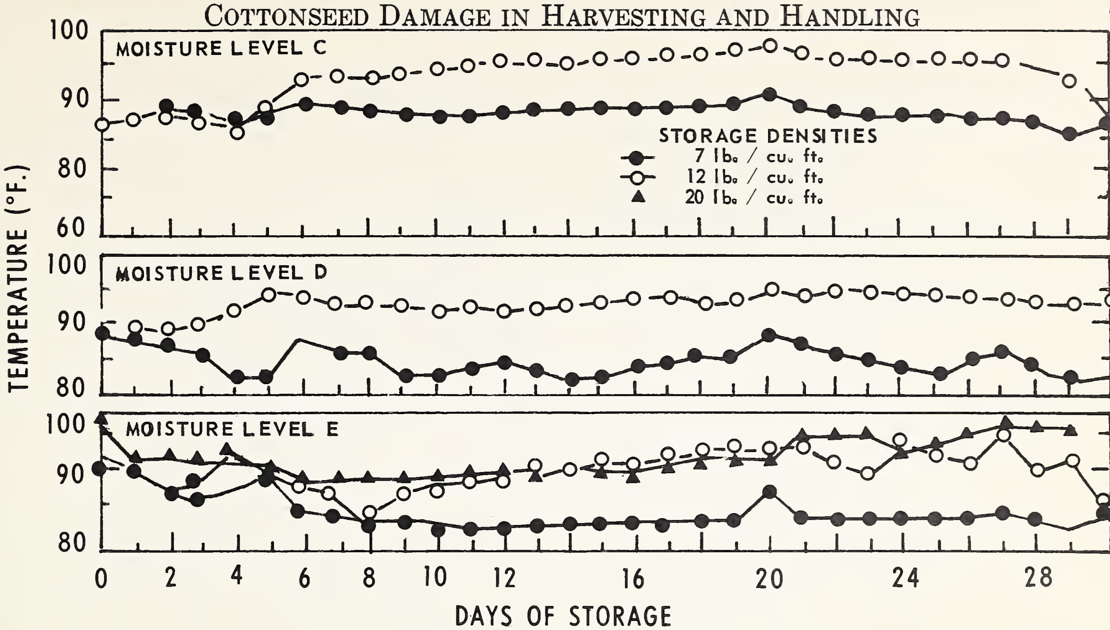


Figure 43.—Temperatures in seed cotton for 30 days of storage: Average moisture contents of seed cotton that was stored for time periods of 3, 5, 10, 20, and 30 days ranged from 12.4 to 15.2 percent for moisture level C, 10.4 to 12.9 percent for moisture level D, and 8.0 to 9.6 percent for moisture level E.

Table 27.—*Germination of cottonseed from seed cotton stored at different moisture levels and storage densities for various lengths of time before ginning*

Moisture level and storage density per cubic foot	Seed moisture content [1]		Germination after the following days of storage					
	Max.	Min.	0	3	5	10	20	30
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Moisture level A:								
7 pounds	24.9	18.2	64.9	71.2	50.2	0	0	0
12 pounds	24.9	18.9	69.3	61.5	11.3	0	0	0
Moisture level B:								
7 pounds	16.1	20.2	77.0	60.2	56.3	17.5	0	0
12 pounds	15.0	19.6	77.8	70.7	55.5	9.2	0	0
Moisture level C:								
7 pounds	11.8	14.1	74.9	75.5	69.3	66.7	59.0	51.0
12 pounds	12.3	15.5	69.8	76.2	65.3	57.3	18.3	42.8
Moisture level D:								
7 pounds	9.8	12.7	79.7	80.2	79.0	77.2	73.1	69.4
12 pounds	8.9	12.4	82.5	79.0	70.2	65.0	77.0	53.7
Moisture level E:								
7 pounds	7.8	9.9	75.1	78.5	73.0	73.4	87.7	64.7
12 pounds	7.0	10.3	71.5	79.5	75.5	74.7	80.0	67.3
20 pounds	8.0	9.8	78.6	79.8	75.8	72.7	75.3	72.8

[1] Range of seed moisture contents at each moisture level for storage of 3 to 30 days, inclusive. The moisture for zero days' storage is not included. See table 26 for average moisture contents of seed and seed cotton for each storage period.

lishing precise relationships between seed moisture content and length of storage difficult. Factors that contribute to this loss in quality are not definitely known. However, cotton used in these tests was not harvested until all the bolls were open and the quality probably deteriorated during the field exposure period before harvest.

Based on an analysis of germination and free fatty acid results for 1966 and 1967 and aflatoxin assays, the following conclusions appear to be justified:

Seed cotton containing seed with 8 to 10 percent moisture can be stored at a density of 20 pounds per cubic foot for as long as 30 days without deterioration in seed quality.

Seed cotton containing seed with the following moisture contents can be stored at densities of 7 and 12 pounds per cubic foot for the time periods shown without loss in seed quality:

Seed moisture content (percent)	Length of storage (days)
8–10	30
10–12	20
12–14	10
14–15	3

Seed quality will be impaired in less than 3 days when the moisture content of seed in stored seed cotton exceeds 15 percent.

The seed moisture contents given above are the maximums for any lot of seed cotton and do not refer to average moisture contents.

Seed Damage

Results of tests to determine the extent of damage to seed are presented in table 29. Any seed that had a visible cut or break in the seed-

TABLE 28.—*Free fatty acid content of oil in cottonseed from seed cotton stored at different moisture levels and storage densities for various lengths of time before ginning*

Moisture level and storage density per cubic foot	Seed moisture content [1]		Free fatty acid content after the following days of storage					
	Max.	Min.	0	3	5	10	20	30
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Moisture level A:								
7 pounds	24.9	18.2	0.9	1.7	2.4	3.1	4.5	5.0
12 pounds	24.9	18.9	1.0	1.2	1.6	2.0	2.2	2.4
Moisture level B:								
7 pounds	16.1	20.2	.9	1.1	1.8	3.1	4.2	9.0
12 pounds	15.0	19.6	1.0	1.2	1.6	2.8	3.1	4.1
Moisture level C:								
7 pounds	11.8	14.1	.3	.3	.4	.4	.6	.7
12 pounds	12.3	15.5	.3	.3	.4	.4	4.8	1.6
Moisture level D:								
7 pounds	9.8	12.7	.3	.3	.3	.4	.4	.3
12 pounds	8.9	12.4	.3	.4	.4	.4	.5	.3
Moisture level E:								
7 pounds	7.8	9.9	.3	.3	.4	.4	.3	.3
12 pounds	7.0	10.3	.3	.3	.3	.4	.3	.6
20 pounds	8.0	9.8	.3	.3	.3	.4	.3	.3

[1] Range of seed moisture contents at each moisture level for storage periods of 3 to 30 days, inclusive. The moisture contents of the seed for zero days' storage are not included. See table 26 for average moisture contents of seed and seed cotton for each storage period.

TABLE 29.—*Percentage of seed damaged in field and during mechanical harvesting and ginning operations, by moisture content of seed at ginning*

Average moisture content of seed (percent, wet basis)	Total seed damage [1]	Damage due to—	
		Field exposure and mechanical harvesting [2]	Ginning operation
	Pct.	*Pct.*	*Pct.*
22.2	18.8	5.3	13.5
17.2	12.3	4.6	7.7
13.3	12.3	7.1	5.2
10.8	10.6	5.5	5.1
7.6	8.3	4.6	3.7

[1] 3 possible sources of damage in these tests were (1) exposure in the field; (2) the mechanical picker; and (3) the ginning process.

[2] Samples were hand ginned.

coat was classified as damaged. Three possible sources of damage in these tests were (1) exposure in the field, (2) the mechanical picker, and (3) the ginning process.

As shown in table 29, mechanical damage due to the ginning operation ranged from 3.7 percent for seed with an average moisture content of 7.6 percent to 13.5 percent damage for seed containing 22 percent moisture. The percentage of damaged seed from comparative samples that were hand ginned ranged from 4.6 to 7.1 percent, indicating the extent of damage occurring in the field or during mechanical harvesting operation or from both sources.

Summary

Research was started in 1965 to study the effects of certain preharvest environmental conditions and preginning storage on the quality of the seed.

The quality of seed obtained from cotton exposed in the field for twice-over harvest methods was not correlated with the length of field exposure time and varied from year to year. However, when cotton was exposed in the field for a long enough period for a once-over harvest, the seeds were consistently of low quality. As a result, no one exposure period could be established to insure obtaining high-quality seed with any of the harvesting procedures used.

In a once-over harvest, germination of seed from the bottom half of the plant was always significantly reduced and free fatty acid content increased when compared with the same quality measurements for seed from the top half of the plant. When the factors that contributed to this loss in quality were considered, the microclimate surrounding the plant appeared to be an important factor in determining the extent of deterioration in seed quality.

The term relative humidity hour (R.H.-hour) was adopted to relate certain microenvironmental factors to seed quality. For any one hour, when the relative humidity is above a predetermined base, there are as many R.H.-hours as there are percentage points relative humidity above the designated base. In one year's research, a significant loss in germination occurred after a field exposure period involving 3,384 to 4,352 R.H.-hours (using an 85 percent base) or 289 to 366 accumulated hours above 85 percent relative humidity, based on the air conditions surrounding the plant.

When cotton is grown under climatic and plant-growth conditions similar to those encountered in this research, several harvests during any one year probably would be necessary to insure obtaining high-quality seed. However, to meet the demands of the future for

increased efficiency in mechanized cotton production, efforts should be made to produce high-quality seed using a once-over harvest. Results of this research indicate that this can be done by (1) providing a more favorable environment surrounding the plant during the fruiting period, and (2) reducing the length of time open bolls are exposed in the field before harvest. To provide these conditions would require certain modifications of the cotton plant.

Seed cotton containing seed at five levels of moisture was stored at three densities for various lengths of time before ginning to determine the effects of different storage conditions on the quality of seed. The seed moisture content was a more accurate basis for safe storage than the seed cotton moisture content.

The temperature of stored seed cotton was a good indication of the length of time seed cotton can be held in storage before ginning without a loss in seed quality. An increase in temperature indicates unfavorable conditions for maintaining quality, and if this occurs, the cotton should be ginned or the cause of heating eliminated as soon as possible.

Aflatoxins were not detected in seed cotton containing seed which are sufficiently high in moisture for biological activity to cause rapid increases in temperature to 100° F. or higher. Aflatoxins were found after 20 days' storage in seed containing 14.8 to 15.5 percent moisture when temperatures of seed cotton did not exceed 97°. Aflatoxins were also present in some samples of seed cotton dried immediately after the cotton was picked, indicating that aflatoxins developed in the field before harvest.

Seed cotton with various moisture content of seed can be stored at densities up to 12 pounds per cubic foot without a loss in seed quality, based on germination, free fatty acid content, and aflatoxin analyses as follows:

Moisture content of seed (percent)	Length of storage (days)
8–10[1]	30
10–12	20
12–14	10
14–15	less than 3

[1] Seed cotton containing seed with 8–10 percent moisture was stored at a density of 20 pounds per cubic foot for 30 days without loss in seed quality.

Mechanical damage due to the ginning operation ranged from 3.7 percent for seed with an average moisture content of 7.6 percent to 13.5 percent damage for seed containing 22.2 percent moisture. The percentage of damaged seed from comparative samples which were hand ginned ranged from 4.6 to 7.1 percent, indicating the extent of damage occurring in the field, or during the mechanical harvesting operation or from both of these.

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